REPORT

GEOLOGIC HAZARDS REVIEW

WELCOME CENTER SUBDIVISION LOT 1

3632 NORTH WOLF CREEK DRIVE

EDEN, WEBER COUNTY, UTAH

Prepared for

Mountain Luxury Real Estate
2460 North Highway 162, Suite 3
Eden, Utah 84310

September 29, 2020

Prepared by

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September 29, 2020

Michelle White
Mountain Luxury Real Estate
2460 North Highway 162, Suite 3
Eden, Utah 84310

SUBJECT: Geologic Hazards Review
Welcome Center Subdivision Lot 1
3632 North Wolf Creek Drive
Eden, Weber County, Utah

Dear Ms. White:

This report presents the results of a reconnaissance-level engineering geology and geologic hazards review and evaluation conducted by Western Geologic & Environmental LLC (Western Geologic) for Welcome Center Subdivision Lot 1 at 3632 North Wolf Creek Drive in Eden, Utah (Figure 1 – Project Location). The Project consists of a 1.25-acre parcel identified as Weber County Assessor parcel number 22-287-0001. The site is located in northeastern Ogden Valley on southwest-facing slopes about 2,000 feet southwest of Wolf Creek, and is in the SW ¼ of Section 22, Township 7 North, Range 1 East (Salt Lake Base Line and Meridian; Figure 1). Elevation of the site is 5,161 to 5,202 feet above sea level. The Project is currently developed by a 5,923 square-foot commercial building constructed in 2007. It is our understanding that the property is under consideration for a real estate transaction. No new structures are planned.

PURPOSE AND SCOPE

The purpose and scope of this investigation is to identify and interpret surficial geologic conditions at the site and identify potential risk from geologic hazards to the Project. This investigation is intended to: (1) provide preliminary geologic information and assessment of geologic conditions at the site; (2) identify potential geologic hazards that may be present and qualitatively assess their risk to inform the purchase decision; and (3) provide recommendations to further assess or mitigate high-risk hazards, as may be needed based on our findings. No hazard-specific evaluations or subsurface exploration were conducted for this report or within the scope of our study.

The following services were performed in accordance with the above stated purpose and scope:

- A site reconnaissance conducted by an experienced certified engineering geologist to assess the site setting and look for adverse geologic conditions in exterior areas;

- Review of readily-available geologic maps, reports, air photos and other documentation; and

- Evaluation of available data and preparation of this report, which presents the results of our study.

The engineering geology section of this report has been prepared in accordance with Bowman and Lund (2016) and current generally accepted professional engineering geologic principles and practice in Utah. However, we do not include discussion of radon hazard potential, as recommended in Bowman and Lund (2016), because radon gas poses an environmental health hazard and indoor levels are heavily influenced by several post-construction, non-geologic factors. The hazard from radon is best evaluated by long-term testing.

HYDROLOGY

The U.S. Geological Survey (USGS) topographic map of the Huntsville Quadrangle shows the site is on the northeast margin of Ogden Valley south of the mouth of Wolf Creek Canyon (Figure 1). No perennial or intermittent drainages are mapped on Figure 1 or were observed crossing the site; although several springs are in the area (including Patio Springs), no springs are also mapped at the Project on Figure 1.

The site is at the northeastern margin of Ogden Valley, which is dominated in the valley bottom by unconsolidated lacustrine and alluvial basin-fill deposits. Slopes in the site area are in a range-front recharge zone dominated by alluvial and colluvial deposits derived from the mountain range front to the northeast, which is characterized by weathered Cambrian-age quartzite bedrock, as well as lacustrine deposits from late Pleistocene Lake Bonneville. Several water wells are shown nearby on Figure 1. Based on the reported depths in the nearest wells, we anticipate groundwater at the Project is between 15 to 40 feet deep. However, groundwater depths at the site likely fluctuate annually and seasonally. Such variations would be typical for an alpine environment. Perched conditions over low permeability, clay-rich layers may also be present locally.

Avery (1994) indicates groundwater in Ogden Valley occurs under perched, confined, and unconfined conditions in the valley fill to depths of 750 feet or more. A well-stratified lacustrine silt layer forms a leaky confining bed in the upper part of the valley-fill aquifer. The aquifer below the confining beds is the principal aquifer, which is in primarily fluvial and alluvial-fan deposits. The principal aquifer is recharged from precipitation, seepage from surface water, and subsurface inflow from bedrock into valley fill along the valley margins (Avery, 1994). The confined aquifer is typically overlain by a shallow, unconfined aquifer recharged from surface flow and upward leakage. Groundwater flow is generally from the valley margins into the valley fill, and then toward the head of Ogden Canyon (Avery, 1994). Based on topography, we expect groundwater flow in the area to be to the south-southwest.

GEOLOGY

Surficial Geology

The site is located on the northeastern margin of Ogden Valley, a sediment-filled intermontane valley within the Wasatch Range, a major north-south trending mountain range marking the eastern boundary of the Basin and Range physiographic province (Stokes; 1977, 1986). Surficial geology of the site is mapped by Coogan and King (2016; Figure 2) as transgressive and Bonneville-shoreline alluvial and deltaic deposits on the northwest, and Holocene- to late Pleistocene-age landslide deposits on the southeast (units Qadb and Qms, respectively; underlined and described below).

Coogan and King (2016) describe surficial geologic units in the site area on Figure 2 as follows:

> ***Qh, Qh?*** - *Human disturbances (Historical).* Mapped disturbances obscure original deposits or rocks by cover or removal; only larger disturbances that pre-date the 1984 aerial photographs used to map the Ogden 30 x 60- minute quadrangle are shown; includes engineered fill, particularly along Interstate Highways 80 and 84, the Union Pacific Railroad, and larger dams, as well as aggregate operations, gravel pits, sewage-treatment facilities, cement plant quarries and operations, brick plant and clay pit, Defense Depot Ogden (Browning U.S. Army Reserve Center), gas and oil field operations (for example drill pads) including gas plants, and low dams along several creeks, including a breached dam on Yellow Creek.
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> ***Qay, Qa2, Qa2?, Qa3, Qa3?, Qa4, Qa4?, Qa4-5, Qa5, Qa6*** - *Alluvium (Holocene and Pleistocene).* Sand, silt, clay, and gravel in stream and alluvial-fan deposits that are not close to late Pleistocene Lake Bonneville and are geographically in the Huff Creek and upper Bear River drainages; variably sorted; variably consolidated; composition depends on source area; deposits lack fan shape of Qaf and are distinguished from terraces (Qat) based on upper surface sloping toward adjacent streams from sides of drainage, or are shown where fans and terraces are too small to show separately at map scale; Qay is at to slightly above present drainages and not incised by active drainages, so is the youngest unit; generally 6 to 20 feet (2-6 m) thick.
>
> Age-number and letter suffixes on alluvium (undivided, channel, flood plain, terrace, and fan) that is not close to late Pleistocene Lake Bonneville are relative and only apply to the local drainage, with suffix 2 being the second youngest; the relative age is queried where age uncertain, generally due to the height not fitting into the typical order of surfaces. The various numbered deposits listed, Qa2 through Qa6, are 20 to 180 feet (6-55 m) above the Bear River, Saleratus Creek, and Yellow Creek. Qa5 and Qa3? are only used in stacked units (Qa5/Tfb and Qa3?/Tfb).
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> ***Qal, Qal1, Qal2, Qal2?*** - *Stream alluvium and flood-plain deposits (Holocene and uppermost Pleistocene).* Sand, silt, clay, and gravel in channels, flood plains, and terraces typically less than 16 feet (5 m) above river and stream level; moderately sorted; unconsolidated; along the same drainage Qal2 is lower than Qat2 and has likely been

subject to flooding, at least prior to dam building; present in broad plains along the Bear, Ogden, and Weber Rivers and larger tributaries like Deep, Cottonwood, East Canyon, Lost, and Saleratus Creeks, along Box Elder, Heiners, and Yellow Creeks, and in narrower plains of larger tributary streams; locally includes muddy, organic overbank and oxbow lake deposits; composition depends on source area, so in back valleys typically contains many quartzite cobbles recycled from the Wasatch Formation; mostly Holocene, but deposited after regression of Lake Bonneville from the late Pleistocene Provo shoreline; width in Morgan Valley is combined flood plain of Weber River and East Canyon and Deep Creeks; 6 to 20 feet (2-6 m) thick and possibly as much as 50 feet (15 m) along Weber River and thinner in the Kaysville quadrangle; greater thicknesses (>50 feet [15 m]) are reported in Morgan Valley (Utah Division of Water Rights, well drilling database), but likely include Lake Bonneville and older Pleistocene deposits.

Suffixes 1 and 2 indicate ages where they can be separated, with 1 including active channels and 2 including low terraces 10 to 20 feet (3-6 m) above the Weber and Ogden Rivers, and the South Fork Ogden River that may have been in the flood plain prior to damming of these waterways. Qal2 queried in low terraces above Bear River, Saleratus Creek, and Dry Creek where deposits may not be in the flood plain.

Qaf, Qafy, Qaf3, Qaf3?, Qaf4, Qaf4?, Qaf5 - *Alluvial-fan deposits (Holocene and Pleistocene).* Mostly sand, silt, and gravel that is poorly bedded and poorly sorted and that is not close to late Pleistocene Lake Bonneville and is geographically in the Huff Creek and upper Bear River drainages; variably consolidated; includes debris flows, particularly in drainages and at drainage mouths (fan heads); generally less than 60 feet (18 m) thick. Qaf with no suffix used where age uncertain or for composite fans where portions of fans with multiple ages cannot be shown separately at map scale; toes of some fans have been removed by human disturbances, so their age cannot be determined.

Where possible, subdivided into relative ages, indicated by letter and number suffixes (like Qa and Qat suffixes) and relative ages only apply to the local drainage, with unit Qafy being the lowest (youngest) fans and unit 3 may or may not post-date Lake Bonneville. Relative ages of these fans are partly based on heights above present drainages at drainage-eroded edge of fan. The relative age is queried where the age is uncertain, generally due to the height not fitting into the typical order of surfaces. The various deposits listed, Qafy and Qaf3 through Qaf5, are 20 to 140 feet (6-40 m) above and west of Saleratus Creek, and also above Yellow Creek and the Bear River. Qafy fans are active, impinge on present-day floodplains, divert active streams, and overlie low terraces.

Qafp, Qafp?, Qafb, Qafb?, Qafpb, Qafpb? *- Lake Bonneville-age alluvial-fan deposits (upper Pleistocene).* Like undivided alluvial fans, but height above present drainages appears to be related to shorelines of Lake Bonneville and is within certain limits (see table 1); these fans are inactive, unconsolidated to weakly consolidated, and locally dissected; fans labeled Qafp and Qafb are related to the Provo (and slightly lower) and Bonneville shorelines of late Pleistocene Lake Bonneville, respectively, while unit Qafpb is used where fans may be related to the Provo or Bonneville shoreline (for example Qafpb is ~40 feet [12 m] above Lost Creek Valley), or where fans of different ages cannot be shown separately at map scale; Qafp fans typically contain well-rounded, recycled Lake Bonneville gravel and sand and are moderately well sorted; generally 10 to less than 60 feet (3-18 m) thick. Lake Bonneville-age fans are queried where relative age is uncertain (see Qaf for details); fans labeled Qafpb? are above the Bonneville shoreline and might be Qafo or like Qafm; see the note under Qao about two possible ages of older alluvium (Qao, Qato, and Qafo).

Most of the Lake Bonneville-age fans in the James Peak quadrangle are far from the Bonneville shoreline and their age is inferred from their stratigraphic relationship(s) to coeval Pinedale glacial outwash (see age equality in Table 3).

The channels (Qafp/Qdlb) on the Weber River delta and Lake Bonneville fines (Qafp on Qlfb) probably record scour and fill during the rapid drawdown of the lake as it fell from the Bonneville shoreline to the Provo shoreline.

Qap, Qap?, Qab, Qab?, Qapb - *Lake Bonneville-age alluvium (upper Pleistocene).* Like undivided alluvium but height above present drainages appears to be related to shorelines of Lake Bonneville and is within certain limits, and unconsolidated to weakly consolidated; alluvium labeled Qap and Qab is related to Provo (and slightly lower) and Bonneville shorelines of Lake Bonneville (at ~4800 to 4840 feet [1463-1475 m] and 5180 feet [1580 m] in Morgan Valley), respectively; suffixes partly based on heights above adjacent drainages near Morgan Valley (see tables 1 and 2); Qap is typically about 15 to 40 feet (5-12 m) above present adjacent drainages, but is locally 45 feet (12 m) above; Qapb is used where more exact age cannot be determined, typically away from Lake Bonneville, or where alluvium of different ages cannot be shown separately at map scale; Qap is up to about 50 feet (15 m) thick, with Qapb and Qab, at least locally up to 40 and 90 feet (12 and 27 m) thick, respectively. Queried where classification or relative age uncertain (see Qa).

A prominent surface (“bench”) is present on Qap and Qatp at about 4900 feet (1494 m) elevation and about 25 to 40 feet (8-12 m) above the Weber River in Morgan Valley and along the South Fork Ogden River.

In the Devils Slide quadrangle, the Qab that is mapped about 80 to 95 feet (24-29 m) above Round Valley and 40 to 50 feet (12-15 m) above adjacent drainages at the mouth of Geary Hollow appears unique. Based on heights above adjacent drainages, these deposits would be Qao (see table 1), but similar alluvial deposits to the east near Phil Shop Hollow have a Bonneville shoreline cut in them and are much thinner than 40 feet (12 m). The lack of a Bonneville shoreline, and small thickness and heights above drainages indicate the deposits could be a Bonneville shoreline fan-delta.

Qac - *Alluvium and colluvium (Holocene and Pleistocene).* Unsorted to variably sorted gravel, sand, silt, and clay in variable proportions; includes stream and fan alluvium, colluvium, and, locally, mass-movement deposits too small to show at map scale; typically mapped along smaller drainages that lack flat bottoms; more extensive east of Henefer where Wasatch Formation (Tw) strata easily weather to debris that "chokes" drainages; 6 to 20 feet (2-6 m) thick. Some deposits are "perched" on benches 80 feet (25 m) and more above present-day drainages like Left Fork Heiners Creek (Heiners Creek quadrangle) and Harris Canyon (Henefer quadrangle). In the Devils Slide quadrangle, some deposits are "perched" on benches about 60 to 130 feet (18-40 m) above Quarry Cottonwood Canyon indicating the alluvium is at least partly Lake Bonneville age and older (see Qab and Qao in tables 1 and 2).

***Qms, Qms?, Qmsy, Qmsy?, Qmso, Qmso?** - Landslide deposits (Holocene and upper and middle? Pleistocene).* Poorly sorted clay- to boulder sized material; includes slides, slumps, and locally flows and floods; generally characterized by hummocky topography, main and internal scarps, and chaotic bedding in displaced blocks; composition depends on local sources; morphology becomes more subdued with time and amount of water in material during emplacement; Qms may be in contact with Qms when landslides are different/ distinct; thickness highly variable, up to about 20 to 30 feet (6-9 m) for small slides, and 80 to 100 feet (25-30 m) thick for larger landslides. Qmsy and Qmso queried where relative age uncertain; Qms queried where classification uncertain. Numerous landslides are too small to show at map scale and more detailed maps shown in the index to geologic mapping should be examined.

Qms without a suffix is mapped where the age is uncertain (though likely Holocene and/or late Pleistocene), where portions of slide complexes have different ages but cannot be shown separately at map scale, or where boundaries between slides of different ages are not distinct. Estimated time of emplacement is indicated by relative-age letter suffixes with: Qmsy mapped where landslides deflect streams or failures are in Lake Bonneville deposits, and scarps are variably vegetated; Qmso typically mapped where deposits are "perched" above present drainages, rumpled morphology typical of mass movements has been diminished, and/or younger surficial deposits cover or cut Qmso. Lower perched Qmso deposits are at Qao heights above drainages (95 ka and older) and the higher perched deposits may correlate with high level alluvium (QTa) (likely older than 780 ka) (see table 1). Suffixes y and o indicate probable Holocene and Pleistocene ages, respectively, with all Qmso likely emplaced before Lake Bonneville transgression. These older deposits are as unstable as other slides, and are easily reactivated with the addition of water, be it irrigation or septic tank drain fields.

***Qls, Qls?, Qlsp, Qlsb, Qlsb?** - Lake Bonneville sand (upper Pleistocene).* Mostly sand with some silt and gravel deposited nearshore below and near the Provo shoreline (Qlsp) and between the Provo and Bonneville shorelines (Qlsb); Qls mapped downslope from slope break below Provo shoreline beach deposits where thin Lake Bonneville regressional sand may overlie transgressional sand; grades downslope into unit Qlf with decreasing sand content and laterally with more gravel into units Qdlp, Qdlb, and upslope with more gravel into unit Qlgb; Qls and Qlsb queried where grain size or unit identification uncertain; may be as much as 75 feet (25 m) thick, and thickest near Ogden; typically less than 20 feet (6 m) thick in Morgan Valley; may include small deltas and deltas that lack typical delta shape.

Qadb, Qadb? *- Transgressive and Bonneville-shoreline alluvial and deltaic deposits (upper Pleistocene).* Cobbly gravel, sand, silt, and clay deposited above (subaerial) and in Lake Bonneville (subaqueous); typically mapped where shorelines are obscure, so that lines cannot be drawn between alluvial fan and delta; include rounded to subangular clasts in a matrix of sand and silt with interbeds of sand and silt; mapped above the Provo shoreline and deposited as lake transgressed to and was at the Bonneville shoreline; typically better sorted delta and lake deposits over poorly sorted alluvial-fan deposits; Qadb prominent along Deep Creek (Morgan quadrangle) and Strawberry Creek (Snow Basin quadrangle); 0 to at least 40 feet (0-12+ m) thick.

Note that the Bonneville-shoreline fan-delta unit (Qadb), at 80 to 100 feet (24-30 m) above present drainages, is typically higher than the related alluvial units (Qab, Qafb) (see table 1). A fan-delta is built when an alluvial fan enters a lake or ocean, and includes both the fan and the delta.

Qla, Qla? *- Lake Bonneville lacustrine deposits and post- and pre-Lake Bonneville alluvial deposits, undivided (Holocene and upper? Pleistocene).* Mostly poorly sorted and poorly bedded sand, silt, and clay, with some gravel; mapped where Lake Bonneville deposits are reworked by later stream action or covered by thin stream and fan deposits, and where lake deposits are thin and overlie older alluvial deposits; unit queried where may be dominantly alluvium; deposits typically eroded from shallow Norwood Formation; mostly mapped near Bonneville shoreline; also mapped in Peterson quadrangle along upper Deep Creek above Bonneville shoreline where lake deposits seem to indicate landslide dam of creek; thickness uncertain.

Qafo, Qafo? *- Older alluvial-fan deposits (mostly upper Pleistocene).* Incised and at least locally dissected fans of mostly sand, silt, and gravel that is poorly bedded and poorly sorted; includes debris flows, particularly in drainages and at drainage mouths (fan heads); older fans are typically above the Bonneville shoreline, with an eroded bench at the shoreline; upstream and above the Bonneville shoreline, unit Qafo is topographically higher than fans graded to the Bonneville shoreline (Qafb), and is typically dissected; generally less than 60 feet (18 m) thick. In Mantua Valley, exposed thickness up to about 100 feet (30 m), but water wells (sections 26 and 27, T. 9 N., R. 1 W.) were still in gravelly to bouldery valley fill at depths of 505 and 467 feet (154 and 142 m), respectively, and red coloration that may indicate Wasatch Formation bedrock was not noted (see Bjorklund and McGreevy, 1973, p. 16).

Qafo queried where relative age is uncertain (see Qaf for details), for example in Mantua quadrangle where it is as high as Qafoe in Morgan Valley (see table 1). Qafo queried in East Canyon graben because the deposits are not dissected and some deposits mantle Qafoe (see also unit Qafm above), resulting in a reversal of relative height and only local incision. These irregular deposits are likely the result of salt movement in the East Canyon graben. Our Qafo is roughly shown to south by Bryant (1990) as Qgp (pediment gravel); farther south he showed Qoa (dissected alluvium) adjacent to the East Canyon fault, which may be the QTaf or Qafoe we mapped.

Amino-acid age estimates presented in Sullivan and Nelson (1992) imply Qafo north of Morgan considerably predates Lake Bonneville and is middle Pleistocene in age (>400 ka). However, the Bonneville shoreline is obscure on this fan, and soil-carbonate age estimates (>70-100 ka) and other amino-acid age estimates (~98-155 ka) in Sullivan and others (1988) imply these older fans are related to Bull Lake glaciation (95,000 to 130,000 years old; see Chadwick and others, 1997; Phillips and others, 1997). As noted under Qao, Qafo deposits may contain two ages (levels) of alluvial surfaces that are not easily recognized in Morgan Valley but are recognized upstream in the Henefer and Lost Creek Valleys (Devils Slide quadrangle) and along the North and South Forks of Ogden River.

Qafoe-QTaf *- Older eroded fan and/or pediment-mantle deposits (middle or lower Pleistocene).* Gravel, sand, silt, and clay in alluvium and colluvium that cap surfaces that are partly correlative with the pre-Lake Bonneville McKenzie Flat geomorphic surface of Williams (1948) (see McCalpin, 1989); in Paradise quadrangle, McCalpin (1989) described this unit (his afo) as forming dissected surfaces 50 to 1000 feet (15-300 m) above active streams, and commonly present as a relatively thin discontinuous veneer, less than 33 feet (10 m) thick, on a surface (pediment) “cut” on Tertiary Salt Lake Formation; but our mapping, which reduces colluvium bias (“slough”), indicates the surface edges are about 100 to 400 feet (30-120 m) above adjacent drainages.

McKenzie Flat is a gently north-inclined little-dissected bench capped by these deposits in the James Peak and Paradise quadrangles, with the flat along the axis of a broad open syncline in the underlying Salt Lake Formation. Dissected surfaces on eroded remnants of these deposits dip west from the East Cache fault zone to McKenzie Flat, with dips that are nearly the same as bedding in the underlying Salt Lake Formation in the east limb of the syncline. This implies the west-dipping surfaces are capped by residual deposits rather than being tilted fan deposits, and the flat may have the same origin. Alternatively the flat and limb deposits have two different origins, fan and lag/residual, respectively. Fans on McKenzie Flat could be middle Pleistocene (McCalpin, 1989; see also Sullivan and Nelson, 1992) (Little Valley or Pokes Point lake cycle) and/or early Pleistocene (after Sullivan and others, 1988) in age; although the lower heights above the adjacent drainages fit this middle and early Pleistocene age (Qafoe), the upper limit is in the range of Quaternary-Pliocene fans (QTaf).

Mullens and Izett (1964) did not map the McKenzie Flat deposits, but described them as an upper 20 to 40 feet (6-12 m) of conglomerate that rests with angular unconformity on the main Salt Lake Formation conglomerate. They noted that exposures in the James Peak quadrangle, pointed out by Dr. C.T. Hardy of Utah State University, show this relationship. The angular unconformity supports a fan origin for the deposits on the north-inclined McKenzie Flat. Mullens and Izett (1964) also noted that subrounded boulders of quartzite derived from Precambrian and Cambrian formations are scattered on McKenzie Flat and boulders average about 1 foot (30 cm) in diameter, but some are as much as 3 feet (90 cm) in diameter.

The Precambrian (Neoproterozoic) and Cambrian quartzite boulders could be recycled from the Salt Lake Formation conglomerate, the Wasatch Formation, or be from quartzite exposures to the south in the James Peak quadrangle. The latter implies transport to the north into lower parts of Cache Valley. When the boulders were transported is more problematic, since they could be a lag from the underlying Salt Lake Formation rather than being transported during Pleistocene fan deposition.

QTcg, QTcg? - *Gravelly colluvial deposits (Pleistocene and/or Pliocene).* Unconsolidated, poorly sorted pebble to cobble to boulder clasts in light-colored gravelly silt and sand matrix that weathers to an indistinct soil; mapped on east side of Ogden Valley; no tuff noticed in soil but thin Norwood Formation may be present in subsurface; rounded quartzite and Paleozoic carbonate clasts are like those upslope in the gravel-rich Wasatch Formation, but matrix not reddish like material typically derived from Wasatch Formation; angular clasts appear to be from underlying Geertsen Canyon Quartzite; unlike younger colluvial gravels (Qcg), stone stripes, which trend downhill, are not present or visible on aerial photographs; generally 6 to 20 feet (2-6 m) thick, but may be as much as 80 feet (25 m) thick. Some QTcg deposits previously shown as Pliocene(?) (Huntsville) fanglomerate (see Lofgren, 1955, in particular figure 19). QTcg queried where material may be units QTng or QTaf.

Tn, Tn? - *Norwood Formation (lower Oligocene and upper Eocene).* Typically light-gray to light-brown altered tuff (claystone), altered tuffaceous siltstone and sandstone, and conglomerate; unaltered tuff, present in type section south of Morgan, is rare; locally colored light shades of red and green; variable calcareous cement and zeolitization; involved in numerous landslides of various sizes; estimate 2000-foot (600 m) thick in exposures on west side of Ogden Valley (based on bedding dip, outcrop width, and topography). Norwood Formation queried where poor exposures may actually be surficial deposits. For detailed Norwood Formation information see description under heading “Sub-Willard Thrust - Ogden Canyon Area” since most of this unit is in and near Morgan Valley and covers the Willard thrust, Ogden Canyon, and Durst Mountain areas.

Cgc, Cgc? - *Geertsen Canyon Quartzite (Middle and Lower Cambrian and possibly Neoproterozoic).* In the west mostly buff (off-white and tan) quartzite, with pebble conglomerate beds; pebbles are mostly rounded light colored quartzite; contains cross bedding, and pebble layers and lenses; colors vary from tan and light to medium gray, with pinkish, orangish, reddish, and purplish hues; outcrops darker than these fresh quartzite colors; cliff forming; some brown-weathering, interbedded micaceous argillite and quartzite common at top and mappable locally; pebble to cobble conglomerate lenses more abundant in middle part of quartzite, and basal, very coarse-grained arkose locally; near Huntsville, total thickness about 4200 feet (1280 m), including upper argillite about 375 feet (114 m) thick and basal coarse-grained arkose (arkosic to feldspathic quartzite) about 300 to 400 feet (90-120 m) thick (Crittenden and others, 1971). Overall seems to be thinner near Browns Hole. Called Prospect Mountain Quartzite and Pioche Shale (argillite at top) by some previous workers.

Upper and lower parts of Crittenden and others (1971; Crittenden, 1972; Sorensen and Crittenden, 1979) are not mappable outside the Browns Hole and Huntsville quadrangles, likely because the marker cobble conglomerate and change in grain size and feldspar content reported by Crittenden and others (1971) is not at a consistent horizon; quartz-pebble conglomerate beds are present in most of the Geertsen Canyon Quartzite.

To the east on leading margin of Willard thrust sheet, the Geertsen Canyon is thinner, an estimated 3200 feet (975 m) total thickness (Coogan, 2006a-b), and may be divided into different members, though informal members to west and east are based on conglomerate lenses near member contact and feldspathic lower member (see Crittenden and others, 1971; Coogan, 2006a-b).

Lower part in west (Cgcl, Cgcl?) is typically conglomeratic and feldspathic quartzite (only up to 20% feldspar reported by Crittenden and Sorensen, 1985a, so not an arkosic), with 300- to 400-foot (90-120 m), basal, very coarse-grained, more feldspathic or arkosic quartzite; 1175 to 1700 feet (360-520 m) thick (Crittenden and others, 1971; Crittenden, 1972; Sorensen and Crittenden, 1979) and at least 200 to 400 feet (60-120 m) thinner near Browns Hole (compare Crittenden, 1972 to Sorensen and Crittenden, 1979). Unit queried where poor exposures may actually be surficial deposits.

Zm, Zm? *- Mutual Formation (Neoproterozoic).* Grayish-red to purplish-gray, medium to thick-bedded quartzite with pebble conglomerate lenses; also reddish-gray, pink, tan, and light-gray in color and typically weathering to darker shades than, but at least locally indistinguishable from, Geertsen Canyon Quartzite; commonly cross-bedded and locally feldspathic; contains argillite beds and, in the James Peak quadrangle, a locally mappable medial argillite unit; 435 to 1200 feet (130-370 m) thick in Browns Hole quadrangle (Crittenden, 1972) and thinnest near South Fork Ogden River (W. Adolph Yonkee, Weber State University, verbal communication, 2006); thicker to northwest, up to 2600 feet (800 m) thick in Huntsville quadrangle (Crittenden and others, 1971) and 2556 feet (780 m) thick in James Peak quadrangle (Blau, 1975); may be as little as 300 feet (90 m) thick south of the South Fork Ogden River (King this report); absent or thin on leading edge of Willard thrust sheet; thins to south and east.

Zmcg, Zmcg? *- Maple Canyon Formation, Lower (green arkose) member (Neoproterozoic).* Grayish-green, fine-grained arkosic (feldspathic) meta-sandstone and sandy argillite (meta-graywacke), with local quartzite lenses up to 200 feet (60 m) thick; weathers darker gray to brown to greenish-gray and greenish-brown; 500 to 1000 feet (150-305 m) thick and lower thickness would eliminate the need for faulting in southwest part of Huntsville quadrangle. This unit is prone to slope failures.

Zkc, Zkc? *- Kelley Canyon Formation (Neoproterozoic).* Dark-gray to black, gray to olive-gray-weathering argillite to phyllite, with rare metacarbonate (for example basal meta-dolomite); grades into overlying Caddy Canyon quartzite with increasing quartzite; gradational interval mapped as Papoose Creek Formation (Zpc); 1000 feet (300 m) thick in Mantua quadrangle (this report), where Papoose Creek Formation is mapped separately, and reportedly 2000 feet (600 m) thick near Huntsville (Crittenden and others, 1971, figure 7), but only shown as about 1600 feet (500 m) thick to Papoose Creek transition zone by Crittenden (1972). The Kelley Canyon Formation is prone to slope failures.

Citations, tables, and figures above are not provided herein, but are in Coogan and King (2016).

Seismotectonic Setting

The property is located at the northeast margin of Ogden Valley, a roughly 40-square mile back valley described by Gilbert (1928) as a structural trough similar to Cache and Morgan Valleys to the north and south, respectively. The back valleys of the northern Wasatch Range are in a transition zone between the Basin and Range and Middle Rocky Mountains physiographic provinces (Stokes, 1977, 1986). The Basin and Range is characterized by a series of generally north-trending elongate mountain ranges, separated by predominately alluvial and lacustrine sediment-filled valleys and typically bounded on one or both sides by major normal faults (Stewart, 1978). The boundary between the Basin and Range and Middle Rocky Mountains provinces is marked by the Wasatch fault zone at the base of the Wasatch Range. Late Cenozoic normal faulting, a characteristic of the Basin and Range, began between about 17 and 10 million years ago in the Nevada (Stewart, 1980) and Utah (Anderson, 1989) portions of the province. The faulting is a result of a roughly east-west directed, regional extensional stress regime that has continued to the present (Zoback and Zoback, 1989; Zoback, 1989). The back valleys are morphologically similar to valleys in the Basin and Range, but exhibit less structural relief (Sullivan and others 1988).

Ogden Valley occupies a structural trough created by up to 2,000 feet of vertical displacement on normal faults bounding the east and west sides of the valley. The Quaternary Fault Database for Utah (Black and others, 2003; updated May 2019) maps the Ogden Valley northeastern margin fault about 1.6 miles northeast of the Project. The most-recent movement on this fault is pre-Holocene (Sullivan and others, 1986). Figure 2 also shows numerous dot-dashed lineaments in the site area, as well as several short fault traces that displace various alluvial and landslide deposits. The faults are not indicated in Black and others (2003) and have uncertain provenance, but based on information in Sullivan and others (1986) are likely pre-Holocene in age. Jon King (Utah Geological Survey, verbal communication, April 2016) indicated that the lineaments have an uncertain origin and appear to correspond to bedding within the underlying bedrock beneath the unconsolidated gravel cap. Coogan and King (2016) reportedly mapped the lineaments because they are also near the Ogden Valley northeastern margin fault and could be related to pre-Holocene faulting. The nearest active (Holocene-age) fault to the site is the Weber section of the Wasatch fault zone about 5.5 miles to the west.

The site is also in the central portion of the Intermountain Seismic Belt (ISB), a generally north-south trending zone of historical seismicity along the eastern margin of the Basin and Range province extending from northern Arizona to northwestern Montana (Sbar and others, 1972; Smith and Sbar, 1974). At least 16 earthquakes of magnitude 6.0 or greater have occurred within the ISB since 1850; the largest of these earthquakes was a M 7.5 event in 1959 near Hebgen Lake, Montana. None of these earthquakes occurred along the Wasatch fault or other known late Quaternary faults (Arabasz and others, 1992; Smith and Arabasz, 1991). The closest event was the 1934 Hansel Valley (M 6.6) event north of the Great Salt Lake. The March 18, 2020 M 5.7 earthquake north of Magna, Utah reportedly showed a style, location, and slip depth consistent with an earthquake on the Wasatch fault system (https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602/executive). Despite being less than magnitude 6.0, this earthquake was felt from southern Idaho to south-central Utah and damaged multiple buildings (https://www.ksl.com/article/46731630/). The University of Utah Seismograph Stations (https://earthquakes.utah.gov/magna-quake/#) indicates the Magna earthquake was weakly felt in Ogden Valley, with a peak acceleration of about 0.005 g and an instrument intensity of II-III (on a Roman numeral scale of I-X).

Lake Bonneville History

Lakes occupied nearly 100 basins in the western United States during late-Quaternary time, the largest of which was Lake Bonneville in northwestern Utah. The Bonneville basin consists of several topographically closed basins created by regional extension in the Basin and Range (Gwynn, 1980; Miller, 1990), and has been an area of internal drainage for much of the past 15 million years. Lake Bonneville consisted of numerous topographically closed basins, including the Salt Lake and Cache Valleys (Oviatt and others, 1992). Portions of Ogden Valley were inundated by Lake Bonneville at its highstand. The lake shoreline is not mapped in the site area, but would be at an elevation similar to units Qla and Qlsb on Figure 2.

Timing of events related to the transgression and regression of Lake Bonneville is indicated by calendar age estimates of significant radiocarbon dates in the Bonneville Basin (Oviatt, 2015). Approximately 30,000 years ago, Lake Bonneville began a slow transgression (rise) to its highest level of 5,160 to 5,200 feet above mean sea level. The lake rise eventually slowed as water levels approached an external basin threshold in northern Cache Valley at Red Rock Pass near Zenda, Idaho. Lake Bonneville reached the Red Rock Pass threshold and occupied its highest shoreline, termed the Bonneville beach, around 18,000 years ago. During the transgression and highstand, major drainages that emanate from within the Wasatch Range (such as the Weber River) formed large deltaic complexes in the lake at their canyon mouths. Headward erosion of the Snake River-Bonneville basin drainage divide then caused a catastrophic incision of the threshold and the lake level lowered by roughly 360 feet in fewer than two months (Jarrett and Malde, 1987; O'Conner, 1993).

Following the Bonneville flood, the lake stabilized and formed a lower shoreline referred to as the Provo shoreline between about 16,500 and 15,000 years ago. Climatic factors then caused the lake to regress rapidly from the Provo shoreline, and by about 13,000 years ago the lake had eventually dropped below historic levels of Great Salt Lake. Drainages that fed Lake Bonneville began downcutting through stranded deltaic complexes and near-shore deposits as the lake receded from the Provo shoreline. Oviatt and others (1992) deem this low stage the end of the Bonneville lake cycle. Great Salt Lake then experienced a brief transgression around 11,600 years ago to the Gilbert level at about 4,250 feet before receding to and remaining within about 20 feet of its historic average level (Lund, 1990).

SITE CHARACTERIZATION

Previous Studies

A water tank is on the northeast-adjoining property that was developed prior to 1997. The water tank reportedly experienced a clogged relief line that saturated downslope areas and produced a slope failure prior to development of the existing building at the Project (Y2 Geotechnical, 2006). The Utah Geological Survey (UGS) observed this landslide in April 1999 and informally terms it the Eden Water Tank Landslide (Appendix A - Photographic Record, Photos 1 and 2).

In June 2006, Y2 Geotechnical (2006) conducted a geologic and geotechnical investigation for the Project. A copy of this report is included in Appendix B, although we note that Y2 Geotechnical indicates two trenches were conducted for their investigation but no trench logs are included. Y2 Geotechnical (2006) reported that, based on their field investigation, the site is covered by up to 12 feet of fill comprised of clayey gravel with cobbles overlying native materials comprised of stiff fat clay with sand. Y2 Geotechnical notes that the failure plane for the 1999 landslide was at the native-fill interface, and the landslide was likely caused by a combination of uncontrolled fill and saturation from the clogged water tank relief line. Y2 Geotechnical (2006) recommended that: (1) the fill materials be completely removed from beneath the building footprint, (2) the building pad be cut level into the native soils, (3) that footings be placed at least 5 horizontal feet into the native fat clay, and (4) that all footings and floor slabs be constructed on at least 24 inches of structural fill to reduce risk from expansive soil. The existing building was developed in 2007 after Y2 Geotechnical's (2006) investigation, but we did not confirm if their recommendations were followed. No slope stability analyses were provided in Y2 Geotechnical's (2006) report and apparently were not therefore performed. In our professional judgement, such analyses would have been prudent given that the site was partly impacted by a known historical landslide.

In August 2008, UGS geologists responded to additional movement of the 1999 landslide and documented evidence for damage to the parking lot at the Project (Appendix A – Photos 3 through 6), as well as to Moose Hollow Drive at the landslide toe (Photos 7 and 8). UGS geologists revisited the site in May 2009 and observed significant additional damage to the parking lot (Appendix A – Photos 9 through 12). In July 2009, UGS geologists observed settlement in the parking lot near the storm drain (Appendix A, Photo 13), a graded area and new drain below the water tank that was flowing substantially (Photo 14), and a significant toe bulge in Moose Hollow Drive (Photos 15 and 16). Curb and gutter had been installed at the toe by April 2014 (Appendix A – Photo 17). In April 2014, UGS geologists also observed backtilting in the sidewalk along the south edge of the parking lot (Appendix A - Photo 19) and damage to the pad for the air conditioning (AC) units southeast of the building (Photo 21). UGS geologists revisited the site three times again in June 2015, June 2018, and April 2019, but noted no indications for new movement or damage (Appendix A – Photos 22 through 26).

Empirical Observations

On September 23, 2020, Bill D. Black, P.G. of Western Geologic conducted a brief reconnaissance of the property and nearby area. Appendix A – Photos 27 through 36 provide a photographic record of our observations. Weather at the time of the site visit was clear and sunny with a temperature of about 73 °F. Two areas of likely seasonal seepage were observed along Moose Hollow Drive south and southeast of the existing building at the Project. The seasonal seep areas are vegetated by phreatophytes and appeared to be near the margins of the water tank landslide. A drain line that was installed in about 2009 discharges to the storm drain sewer in the curb and gutter along the north side of Moose Hollow Drive and was flowing at the time of our reconnaissance. It is unconfirmed if the drain line is part of the water tank infrastructure or if it is for some other drainage system.

No evidence for new movement was noted in Moose Hollow Drive at the toe of the landslide (Photo 27) compared to 2019, and the parking lot pavement appeared to have been repaired since 2012 (Photo 28). Some evidence for either slope instability or settlement was observed at the property during our reconnaissance, but we are uncertain if this evidence was previously present or occurred after the last UGS visit in April 2019. Appendix A – Photo 29 shows displacement in the pad for the transformer; Photo 30 shows a pull-apart gap between the sidewalk and curbing adjacent to the parking lot; Photo 31 shows a cracked support beam for the roof overhang at the entrance, which is likely from shearing/tilting (about 1-2 inches of lateral displacement is shown in the unpainted area); Photos 32 and 33 show a pull-apart gap between the AC pad and building, and a lateral displacement in the pad; Photo 34 shows slight differential settlement in the sidewalk near the building entrance; Photo 35 shows tilting in a concrete patio and minor rock veneer spalling in a support column on the west side of the building; and Photo 36 shows a gap beneath the concrete patio and underlying soils, which may be from downward slope movement or washout erosion beneath the pad.

Air Photo Observations

Pre-development black and white aerial photography from 1997, 1-meter bare earth DEM LIDAR from 2011, and high-resolution orthophotography from 2012 available from the Utah AGRC were reviewed to obtain information about the geomorphology of the Project area (Figures 3A-C, respectively). Site-specific geologic mapping is shown on Figures 3A-C based on our air photo review and Coogan and King (2016).

Figure 3A shows the existing water tank on the adjoining property. Fill materials have been emplaced around the tank and on the Project, likely from excavation during installation of the tank. The 1999 landslide reportedly involved these fill materials, but occurred after the air photo date. Figure 3B shows the approximate boundary of the water tank landslide based on air photo evidence and UGS observations in 2008-2009. Figure 3C shows a geoprocessed LIDAR image of the Project. Red- and yellow-shaded areas represent slopes steeper than 25%, and between 15 to 25% (respectively). These slopes have the highest risk for future instability, particularly if saturated and given the emplaced fill materials. Location of the water tank drain line is shown on Figures 3B-C, but is inferred. We show this feature because it could become important if any future mitigation is conducted or additional parking is developed in the southeast part of the property. Because it appears to cross the site, the drain line location should be confirmed based on as-built drawings, discussions with the water tank owner, or a future utility locate request.

GEOLOGIC HAZARDS

Table 1 below shows a summary of the geologic hazards reviewed at the site, as well as a relative (qualitative) assessment of risk to the Project for each hazard. A "high" hazard rating (H) indicates a hazard that is likely to pose significant risk at the site. A "moderate" hazard rating (M) indicates a hazard that poses an equivocal risk. A "low" hazard rating (L) indicates a hazard that is not present or poses little or no risk. We note that these hazard ratings represent a conservative assessment for the entire site and risk may vary in some areas.

Table 1. *Geologic hazards summary.*

Hazard	H	M	L
Earthquake Ground Shaking	X		
Surface Fault Rupture			X
Liquefaction and Lateral-spread Ground Failure			X
Tectonic Deformation			X
Seismic Seiche and Storm Surge			X
Stream Flooding			X
Shallow Groundwater		X	
Landslides and Slope Failures	X		
Debris Flows and Floods			X
Rock Fall			X
Problem Soil	X		

Earthquake Ground Shaking

Ground shaking refers to the ground surface acceleration caused by seismic waves generated during an earthquake. Strong ground motion is likely to present a significant risk during moderate to large earthquakes located within a 60 mile radius of the Project area (Boore and others, 1993). Seismic sources include mapped active faults, as well as a random or "floating" earthquake source on faults not evident at the surface. The Utah Geological Survey Quaternary Fault Database (Black and others, 2003; January 2017 update) shows numerous class A faults within 60 miles of the Project that may pose potential seismic sources.

The extent of property damage and loss of life due to ground shaking depends on factors such as: (1) proximity of the earthquake and strength of seismic waves at the surface (horizontal motions are the most damaging); (2) amplitude, duration, and frequency of ground motions; (3) nature of foundation materials; and (4) building design. Based on 2018 IBC (ASCE 7-16) provisions, a site class of C (as classified by Y2 Geotechnical in Section 9.2 of their report), and a risk category of II, calculated seismic values for the site (centered on 41.324559 ° N, -111.826828 ° W) are summarized in Table 2 below:

Table 2. *Seismic hazards summary.*

S_S	*0.947 g*
S_1	*0.337 g*
S_{MS} (F_a x S_S)	*1.136 g*
S_{M1} (F_v x S_1)	*0.505*
S_{DS} (2/3 x S_{MS})	*0.758 g*
S_{D1} (2/3 x S_{M1})	*0.337 g*
Site Coefficient, F_a	*= 1.2*
Site Coefficient, F_v	*= 1.5*
Peak Ground Acceleration, PGA	*= 0.42 g*

Given the above information, we rate the risk from earthquake ground shaking as high. Earthquake ground shaking is a regional hazard common to all Wasatch Front areas. The hazard is mitigated by design and construction in accordance with current seismic building codes. The existing building was developed in 2007 and should be in accordance with the seismic code in force at that time. Note that the peak ground acceleration on Table 2 (0.42 g), which would be for a large magnitude earthquake on the Wasatch fault system, is 84 times that experienced in Ogden Valley from the magnitude 5.7 Magna earthquake (0.005 g). However, the chance that such an event will happen during the lifetime of the building is relatively low (2% in 50 years).

Surface Fault Rupture

Movement along faults at depth generates earthquakes. During earthquakes larger than Richter magnitude 6.5, ruptures along normal faults in the intermountain region generally propagate to the surface (Smith and Arabasz, 1991) as one side of the fault is uplifted and the other side down dropped. The resulting fault scarp has a near-vertical slope. The surface rupture may be expressed as a large singular rupture or several smaller ruptures in a broad zone. Ground displacement from surface fault rupture can cause significant damage or even collapse to structures located on an active fault.

No active faults are mapped or were observed at the site or nearby. The nearest active (Holocene-age) fault to the site is the Weber section of the Wasatch fault zone about 5.5 miles to the west. Given the above, the risk from surface faulting is low.

Liquefaction and Lateral-spread Ground Failure

Liquefaction occurs when saturated, loose, cohesionless, soils lose their support capabilities during a seismic event because of the development of excessive pore pressure. Earthquake-induced liquefaction can present a significant risk to structures from bearing-capacity failures to structural footings and foundations, and can damage structures and roadway embankments by triggering lateral spread landslides. Earthquakes of Richter magnitude 5 are generally regarded as the lower threshold for liquefaction. Liquefaction potential at the site is a combination of expected seismic (earthquake ground shaking) accelerations, groundwater conditions, and presence of susceptible soils.

Given the subsurface conditions reported by Y2 Geotechnical (2006) at the Project, no soils susceptible to liquefaction appear to be present. Both Y2 Geotechnical (2006) and Weber County GIS mapping indicate the site has a low liquefaction potential. Based on all the above, the risk from liquefaction is low.

Tectonic Deformation

Tectonic deformation refers to subsidence from warping, lowering, and tilting of a valley floor that accompanies surface-faulting earthquakes on normal faults. Large-scale tectonic subsidence may accompany earthquakes along large normal faults (Lund, 1990). Tectonic subsidence is believed to mainly impact those areas immediately adjacent to the downthrown side of active normal faults. The Project is not in close proximity to and on the downthrown side of any mapped active (Holocene) faults. Based on this, we rate the risk from tectonic subsidence as low.

Seismic Seiche and Storm Surge

Earthquake-induced seiche presents a risk to structures within the wave-oscillation zone along the edges of large bodies of water, such as the Great Salt Lake. Given the elevation of the subject property and distance from large bodies of water, we rate the risk from seismic seiches as low.

Stream Flooding

Stream flooding may be caused by direct precipitation, melting snow, or a combination of both. In much of Utah, floods are most common in April through June during spring snowmelt. High flows may be sustained from a few days to several weeks, and the potential for flooding depends on a variety of factors such as surface hydrology, site grading and drainage, and runoff. Federal Emergency Management Agency flood insurance rate mapping (Map Number 49057C0229F, effective June 2015) classifies the Project in "Zone X - Area of Minimal Flood Hazard". Given the mapping and our observations, we rate the risk from stream flooding as low.

Shallow Groundwater

Based on the reported depths in the nearest water wells on Figure 1, we anticipate groundwater at the Project is between 15 to 40 feet deep. No groundwater was observed in any of the excavations conducted by Y2 Geotechnical (2006). However, groundwater depths at the site likely vary annually and seasonally. Such variations would be typical for an alpine environment. Although groundwater does not appear to pose a significant risk given the above, slopes at the site have been subject to water from an offsite, man-made source. We therefore rate the risk from shallow groundwater as moderate. Groundwater is an important trigger for slope instability, as evidenced by the water tank landslide. Minimizing near-surface groundwater is therefore critical in maintaining slope stability. To prevent water infiltration below the building, Y2 Geotechnical (2006) recommended that: (1) the building include a subsurface drainage system to divert water away from the building, and (2) that downspouts discharge at least 10 feet beyond the backfill (Sections 13.0 and 14.0, Appendix B). We did not confirm if the building has a subsurface drainage system, but the roof downspouts did not appear to discharge as recommended by Y2 Geotechnical. Some of the observed settlement around the building may be from downspout discharge.

Landslides and Slope Failures

Slope stability hazards such as landslides, slumps, and other mass movements can develop along moderate to steep slopes where a slope has been disturbed, the head of a slope loaded, or where increased groundwater pore pressures result in driving forces within the slope exceeding restraining forces. Slopes exhibiting prior failures, and also deposits from large landslides, are particularly vulnerable to instability and reactivation.

Alluvial-deltaic sediments underlie the area of the existing building, but the southeast part of the Project is underlain by deposits from a landslide that is contemporaneous with or post-dates Lake Bonneville. The site has been impacted by a historical landslide reportedly caused by a clogged relief line for the water tank on the east-adjoining property. The landslide was initially documented by the UGS in 1999, prior to development of the existing building. UGS geologists documented damage to exterior areas at the site, after the building was constructed, between

2008 and 2014. We also observed evidence for damage that may be related to slope instability during our site reconnaissance, although we are uncertain if some features were already present in 2014.

Given all the above, we rate the risk from landslides as high. Groundwater is a significant trigger for slope instability. Ensuring that proper surface and subsurface drainage is maintained will minimize water that enters the slopes and thereby reduce the risk of future slope instability. Possible methods include: (1) ensuring that downspout discharge is directed away from the building per Y2 Geotechnical's (2006) recommendations; (2) installing a deep cutoff trench and drain along the eastern property boundary to intercept any future leaks from the water tank before they migrate onsite; (3) installing retaining walls below select areas that have experienced movement or settlement; (4) ensuring that surface drainage does not pond in paved areas and pavement damage does not provide a pathway for infiltration; and (5) installation of soil nails to improve performance of the structure and minimize the effect of any future slope movement. These mitigation options should be discussed with and evaluated by a licensed geotechnical engineer, but are likely to be relatively inexpensive.

Debris Flows

Debris flow hazards are typically associated with unconsolidated alluvial fan deposits at the mouths of large range-front drainages, such as those along the Wasatch Front. Debris flows have historically caused significant damage in the Wasatch Front area. The Project is not in an area currently subject to alluvial-fan flooding and no debris-flow channels, levees, or other debris-flow features were observed during our reconnaissance. We therefore rate the risk from debris flows to the Project as low.

Rock Fall

No large bedrock outcrops were observed upslope or onsite that appeared to pose a significant rock fall source area. Based on the above, we rate the hazard from rock falls as low.

Problem Soil and Rock

Laboratory testing conducted by Y2 Geotechnical (2006) indicated the native fat clay soils at the site are expansive and susceptible to about 2% swelling when wetted. Given this, we rate the risk from problem soils as high. Section 3.0 of their report provided foundation recommendations to address expansive soils. We did not confirm if Y2 Geotechnical's (2006) recommendations were followed.

CONCLUSIONS AND RECOMMENDATIONS

Earthquake ground shaking, landslides and expansive soils pose a high relative risk to the Project. Shallow groundwater from man-made sources also poses a moderate risk. We recommend the following:

- ***Structural Engineering Inspection*** – A structural engineer should inspect interior and exterior areas of the building for evidence of damage from slope instability or settlement. Any damage noted by the structural engineer should be repaired prior to property transfer.

- ***Roof Downspout Discharge*** – The roof downspouts should discharge at least 10 feet away from the building, as recommended by Y2 Geotechnical, to minimize water beneath the building and in disturbed subsurface areas around the building.

- ***Geotechnical Considerations*** – We did not confirm if the design-level recommendations provided in Y2 Geotechnical (2006) were followed, including whether fill materials were removed from beneath the building, if a foundation drainage system was installed, and/or with regard to the footing and foundation installation. We recommend that the owner, architect or builder provide a written statement or other documentation that the geotechnical engineering recommendations were followed.

- ***Landslide Hazard Reduction*** – We recommend that a Utah-licensed geotechnical engineer evaluate and provide possible mitigation options for reducing the risk of damage to the building in the event of future slope instability. Various options are discussed in Landslides and Slope Failures Section above. Costs can be factored into the purchase decision if these options are considered prior to property transfer.

- ***Report Availability*** – This report and any subsequent reports regarding geologic conditions at the property should be made available to the architect and building contractor, as well as real estate agents and potential buyers in the event of a future sale. The report should be referenced for information on technical data only as interpreted from observations and not as a warranty of conditions throughout the site. The report should be submitted in its entirety, or referenced appropriately, as part of any document submittal to a government agency responsible for planning decisions or geologic review. Incomplete submittals void the professional seals and signatures we provide herein. Although this report and the data herein are the property of the client, the report format is the intellectual property of the authors and should not be copied, used, or modified without their express permission.

LIMITATIONS

This investigation was performed at the request of the Client using the methods and procedures consistent with good commercial and customary practice designed to conform to acceptable industry standards. The analysis and recommendations submitted in this report are based upon the data obtained from site-specific observations and compilation of known geologic information. This information and the conclusions of this report should not be interpolated to adjacent properties without additional site-specific information. In the event that any changes are later made in the location of the proposed site, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report modified or approved in writing by the engineering geologist.

This report has been prepared by the staff of Western Geologic for the Client under the professional supervision of the principal and/or senior staff whose seal(s) and signatures appear hereon. Neither Western Geologic, nor any staff member assigned to this investigation has any interest or contemplated interest, financial or otherwise, in the subject or surrounding properties, or in any entity which owns, leases, or occupies the subject or surrounding properties or which may be responsible for environmental issues identified during the course of this investigation, and has no personal bias with respect to the parties involved.

The information contained in this report has received appropriate technical review and approval. The conclusions represent professional judgment and are founded upon the findings of the investigations identified in the report and the interpretation of such data based on our experience and expertise according to the existing standard of care. No other warranty or limitation exists, either expressed or implied.

The investigation was prepared in accordance with the approved scope of work outlined in our proposal for the use and benefit of the Client; its successors, and assignees. It is based, in part, upon documents, writings, and information owned, possessed, or secured by the Client. Neither this report, nor any information contained herein shall be used or relied upon for any purpose by any other person or entity without the express written permission of the Client. This report is not for the use or benefit of, nor may it be relied upon by any other person or entity, for any purpose without the advance written consent of Western Geologic.

In expressing the opinions stated in this report, Western Geologic has exercised the degree of skill and care ordinarily exercised by a reasonable prudent environmental professional in the same community and in the same time frame given the same or similar facts and circumstances. Documentation and data provided by the Client, designated representatives of the Client or other interested third parties, or from the public domain, and referred to in the preparation of this assessment, have been used and referenced with the understanding that Western Geologic assumes no responsibility or liability for their accuracy. The independent conclusions represent our professional judgment based on information and data available to us during the course of this assignment. Factual information regarding operations, conditions, and test data provided by the Client or their representative has been assumed to be correct and complete. The conclusions presented are based on the data provided, observations, and conditions that existed at the time of the field exploration.

It has been a pleasure working with you on the Project. Should you have any questions, please call.

Sincerely,
Western Geologic & Environmental LLC

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ATTACHMENTS

- Figure 1. Location Map (8.5”x11”)
- Figure 2. Geologic Map (8.5”x11”)
- Figure 3A. 1997 Air Photo (8.5”x11”)
- Figure 3B. 2012 Air Photo (8.5”x11”)
- Figure 3C. LIDAR Analysis (8.5”x11”)
- Appendix A. Photographic Record
- Appendix B. Y2 Geotechnical Report

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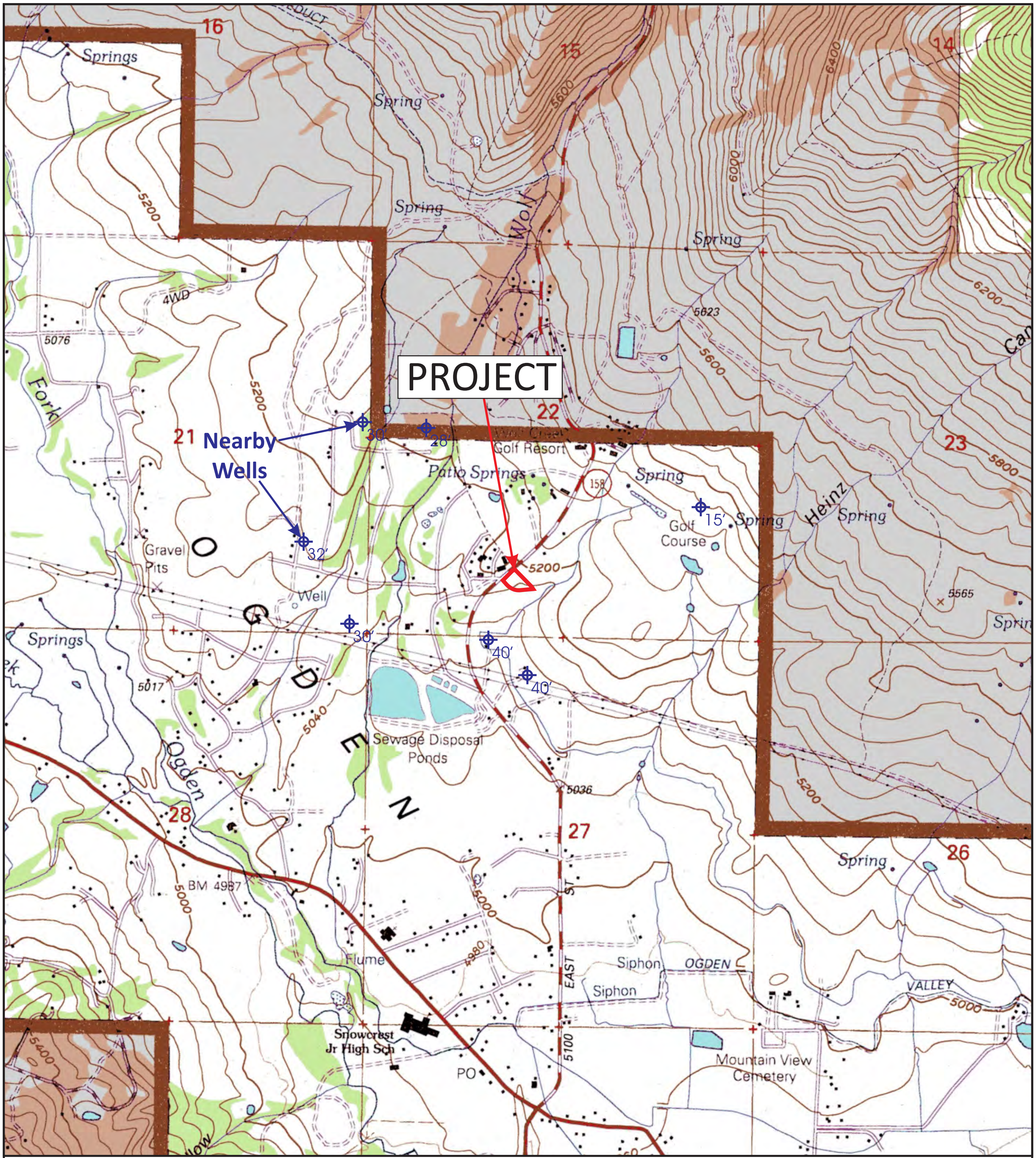
FIGURES



Source: U.S. Geological Survey 7.5 Minute Series Topographic Maps, Utah - Huntsville, 1998;
Project location SW1/4 Section 22, T7N, R1E (SLBM).

WESTERN GEOLOGIC

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W E
S

0 1000 2000 feet

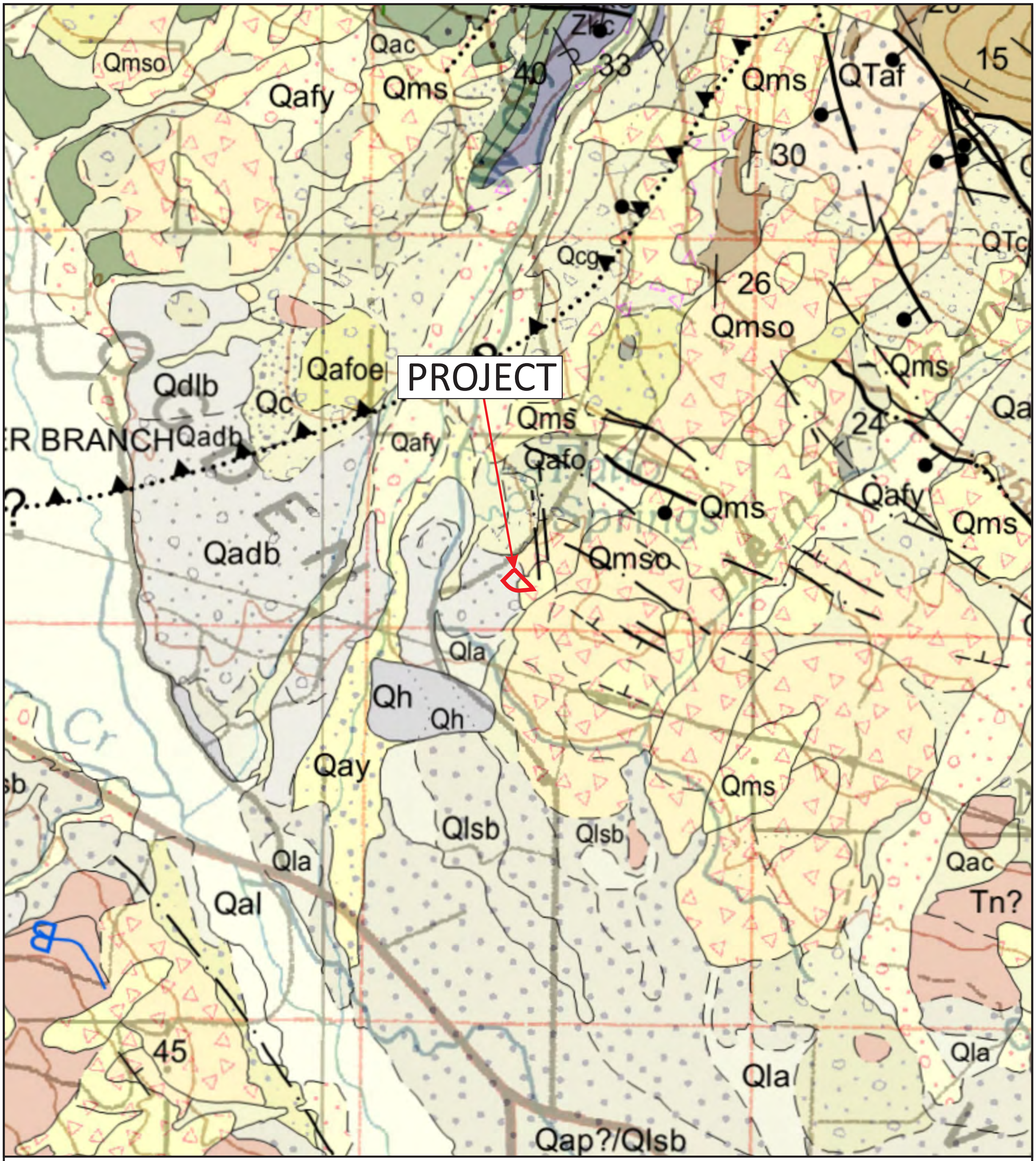
Scale 1:24,000
(1 inch = 2000 feet)

LOCATION MAP

GEOLOGIC HAZARDS REVIEW

Welcome Center Subdivision Lot 1
3632 North Wolf Creek Drive
Eden, Weber County, Utah

FIGURE 1



Source: Coogan and King (2016), original map scale 1:100,000. See text for explanation of nearby surficial geologic units.

Scale 1:24,000
(1 inch = 2000 feet)

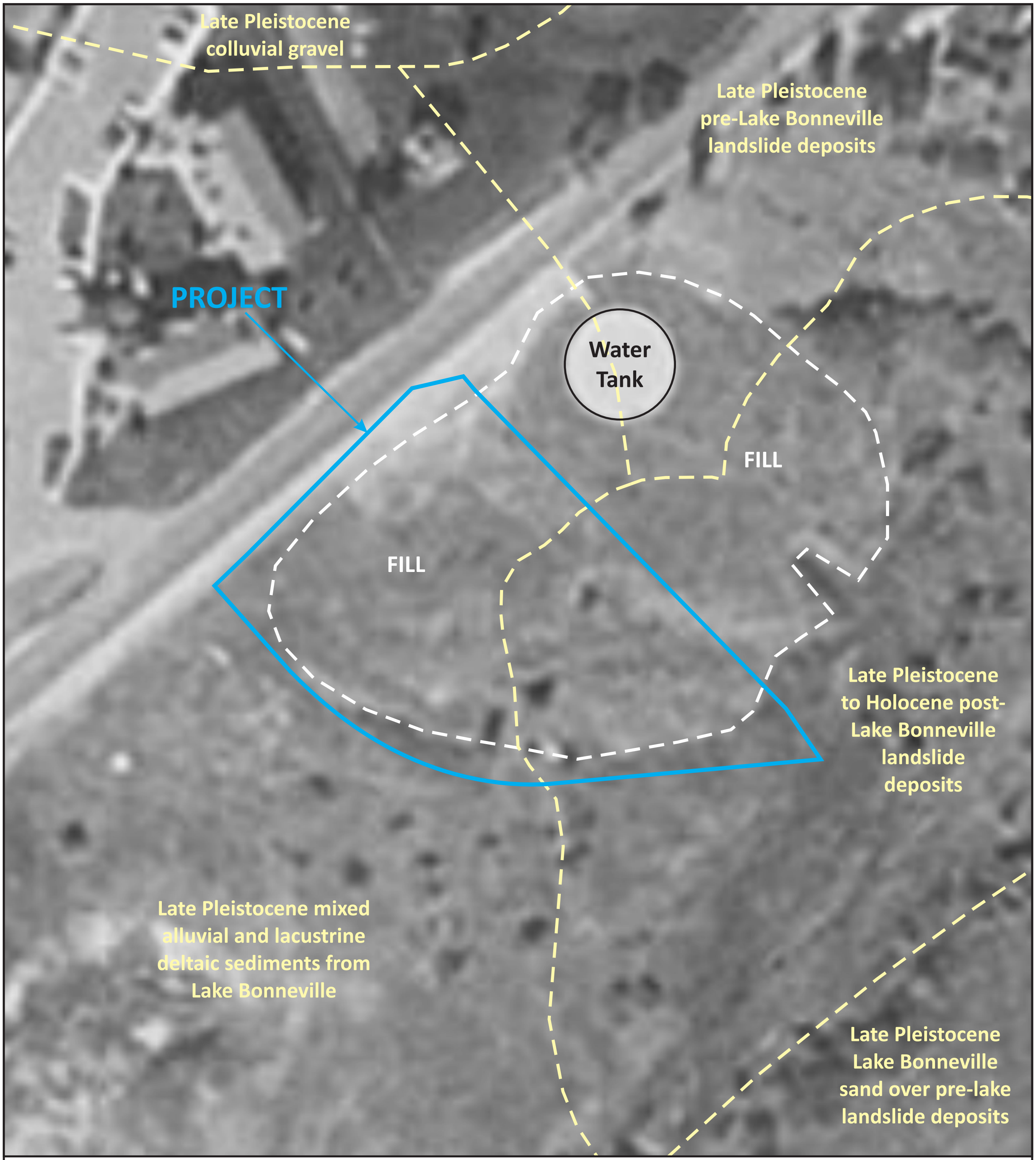
WESTERN GEOLOGIC

GEOLOGIC MAP

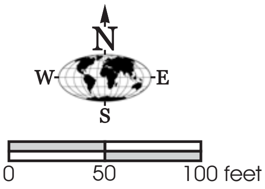
GEOLOGIC HAZARDS REVIEW

Welcome Center Subdivision Lot 1
3632 North Wolf Creek Drive
Eden, Weber County, Utah

FIGURE 2



Source: Utah AGRC 1997 Digital Orthophoto, 1 m resolution.



Scale 1:1,200
(1 inch = 100 feet)

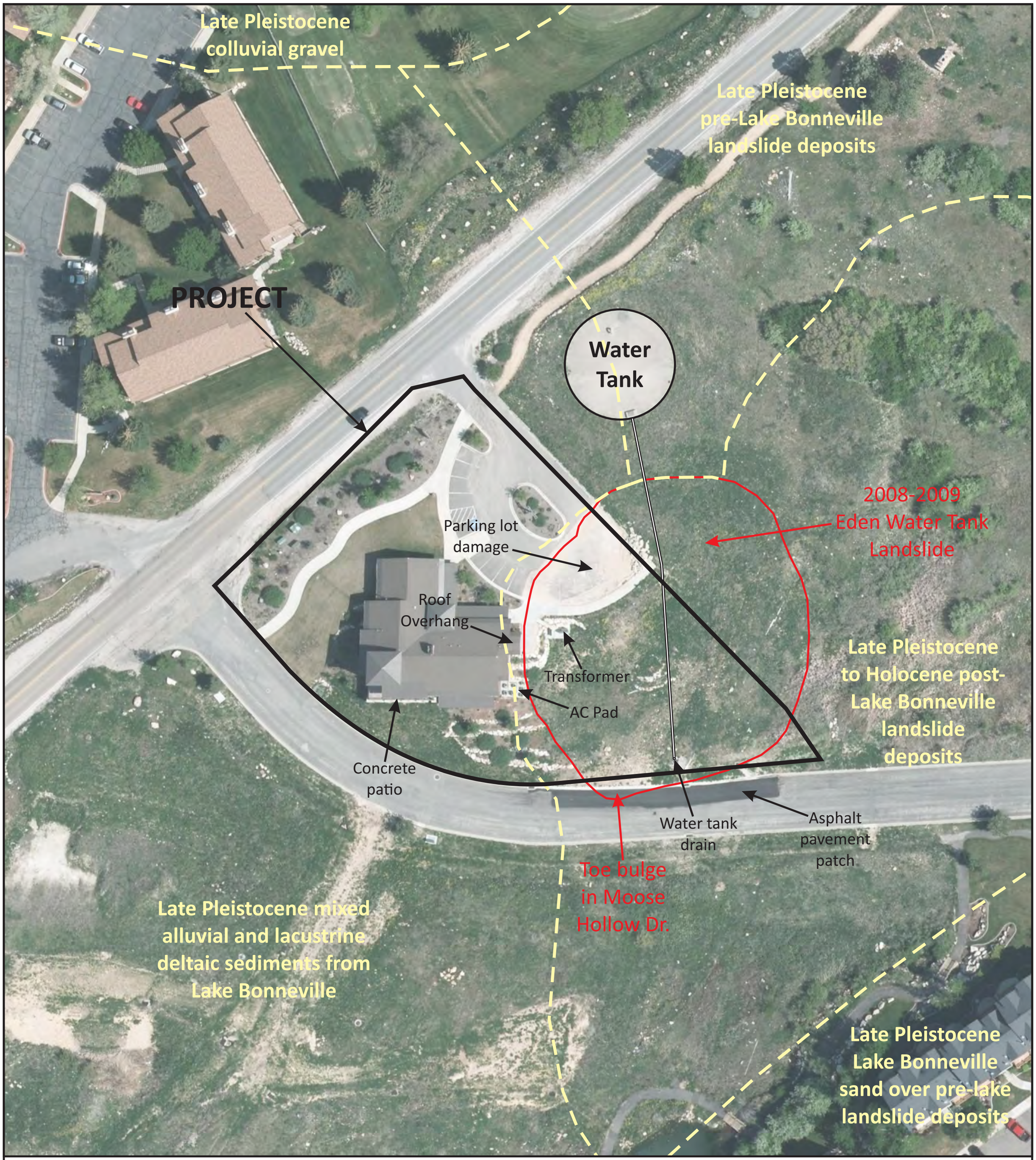
WESTERN GEOLOGIC

1997 AERIAL PHOTO

GEOLOGIC HAZARDS REVIEW

Welcome Center Subdivision Lot 1
3632 North Wolf Creek Drive
Eden, Weber County, Utah

FIGURE 3A



Source: Utah AGRC, 2012 High Resolution Orthophoto, 12.5 cm resolution.

WESTERN GEOLOGIC

N
W E
S

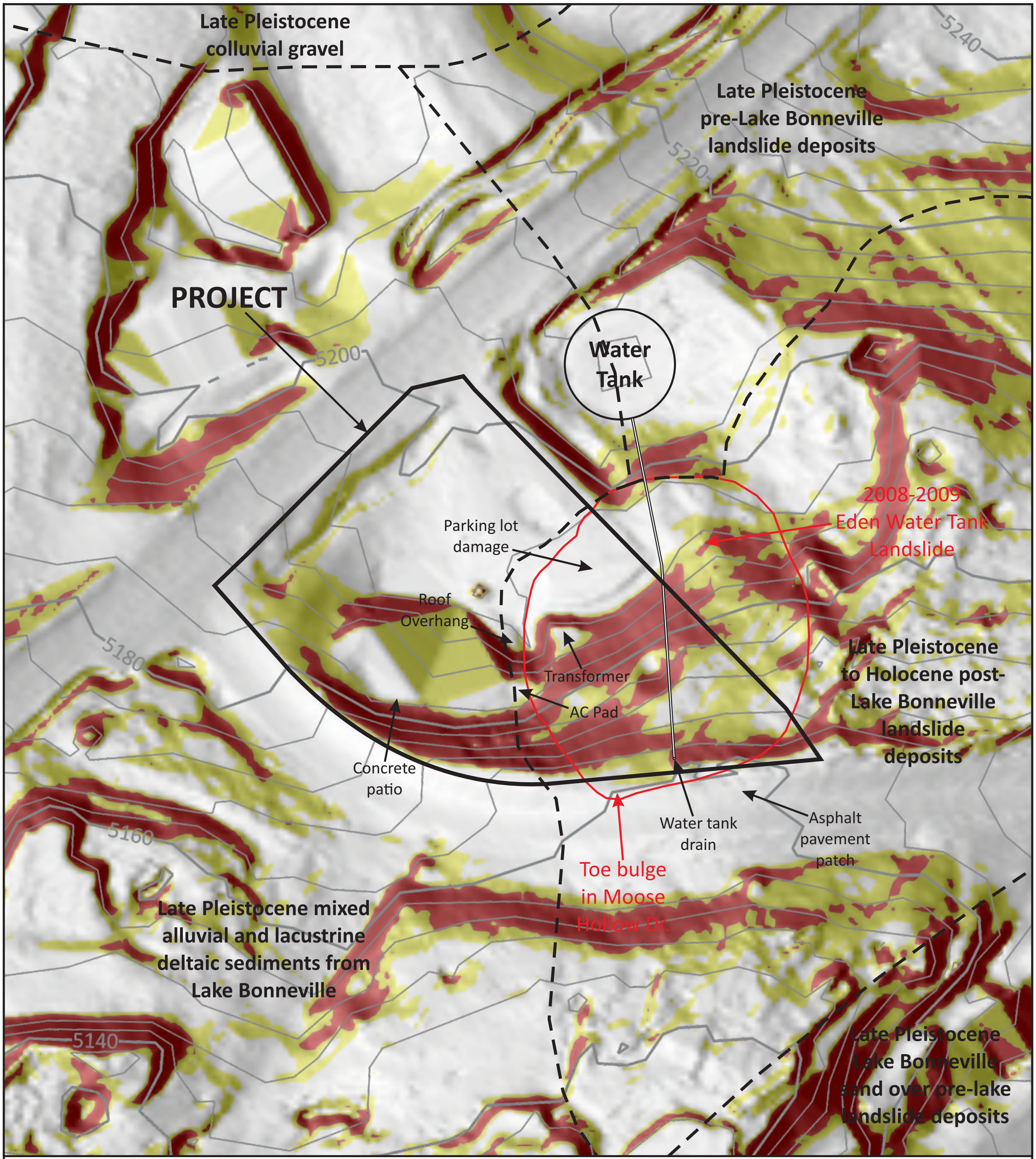
0 50 100 feet

Scale 1:1,200
(1 inch = 100 feet)

2012 AIR PHOTO

GEOLOGIC HAZARDS REVIEW
Welcome Center Subdivision Lot 1
3632 North Wolf Creek Drive
Eden, Weber County, Utah

FIGURE 3B



Source: Utah AGRC, 2011 LIDAR Bare Earth DEM, 1 meter resolution; 4 foot contour interval; slope gradients <15% unshaded, 15-25% in yellow, and >25% in red.

N
W E
S

0 50 100 feet

Scale 1:1,200
(1 inch = 100 feet)

LIDAR ANALYSIS

GEOLOGIC HAZARDS REVIEW

Welcome Center Subdivision Lot 1
3632 North Wolf Creek Drive
Eden, Weber County, Utah

FIGURE 3C

APPENDIX A

PHOTOGRAPHIC RECORD

Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 1. April 1999 UGS site visit. Eden Water Tank Landslide.

Photo 2. April 1999 UGS site visit. Eden Water Tank Landslide.

Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 3. August 2008 UGS site visit. Displacement across parking lot at site.

Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 4. August 2008 UGS site visit. Displacement in side walk and pavement.

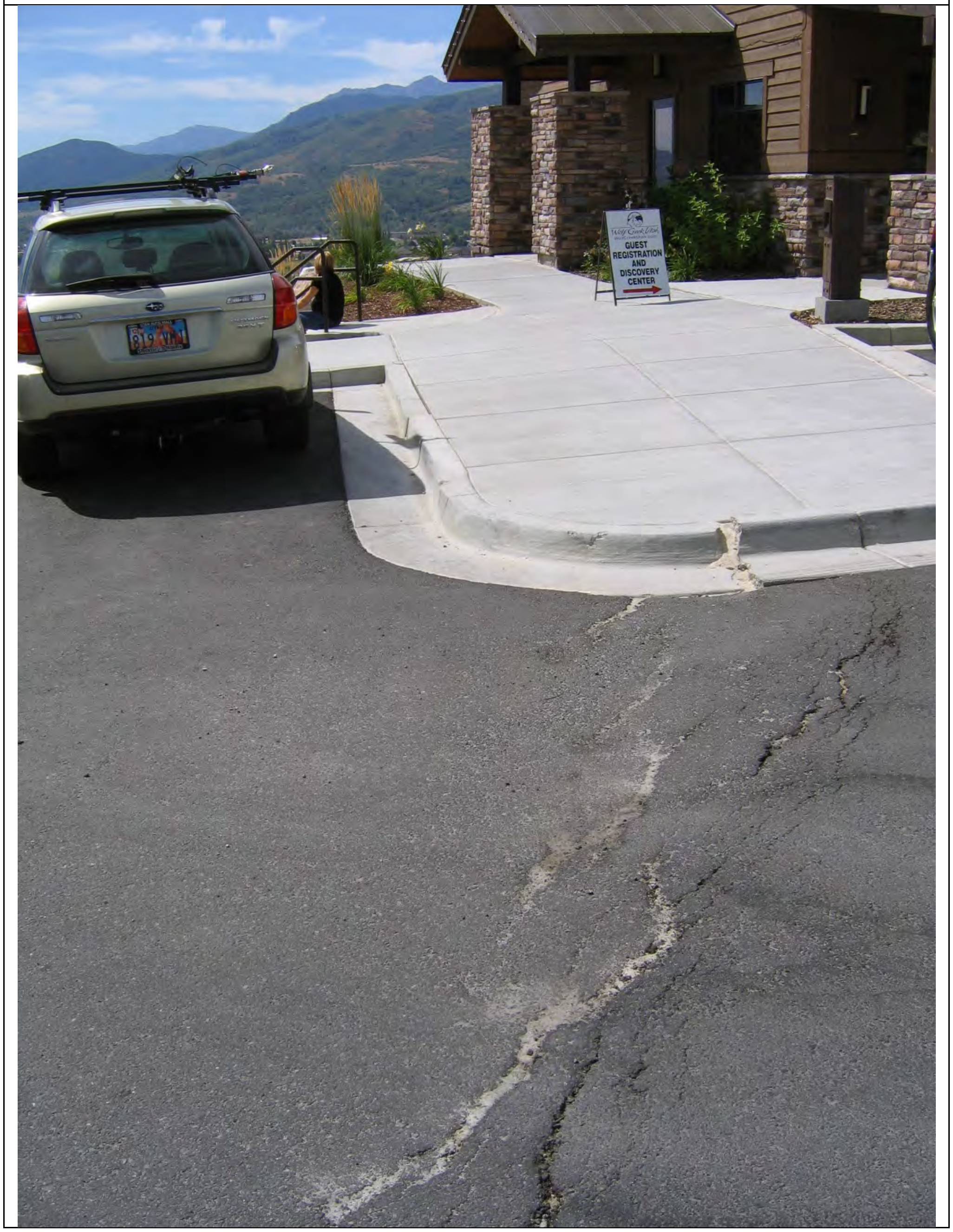
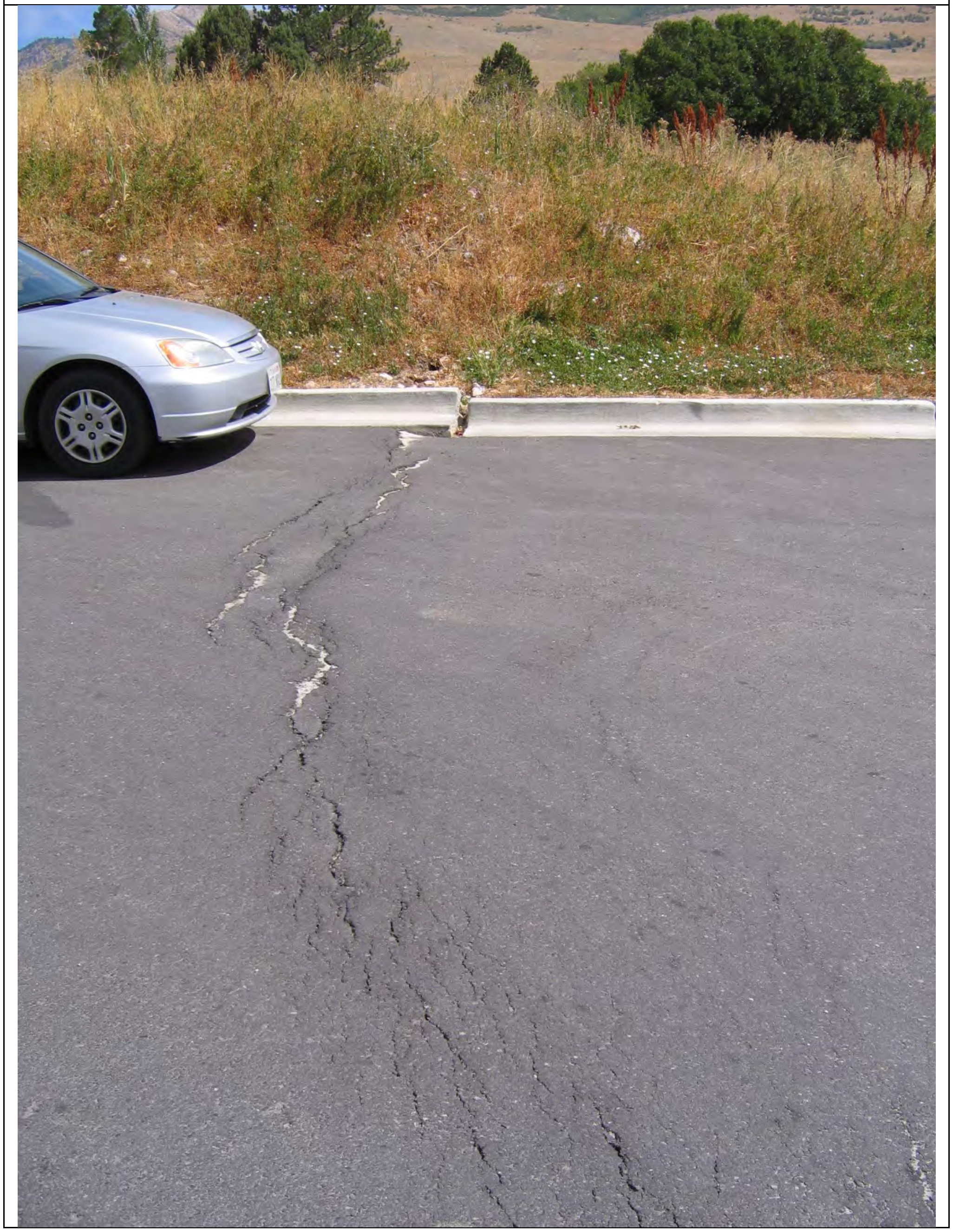


Photo 5. August 2008 UGS site visit. Cracking and displacement in curb and gutter.



Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 6. August 2008 UGS site visit. Displacement in parking lot at site.

Photographic Record
Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 7. August 2008 UGS site visit. Landslide toe at Moose Hollow Drive.

Photo 8. August 2008 UGS site visit. Subtle toe bulge in Moose Hollow Drive.

Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 9. May 2009 UGS site visit. More displacement in parking lot at site.

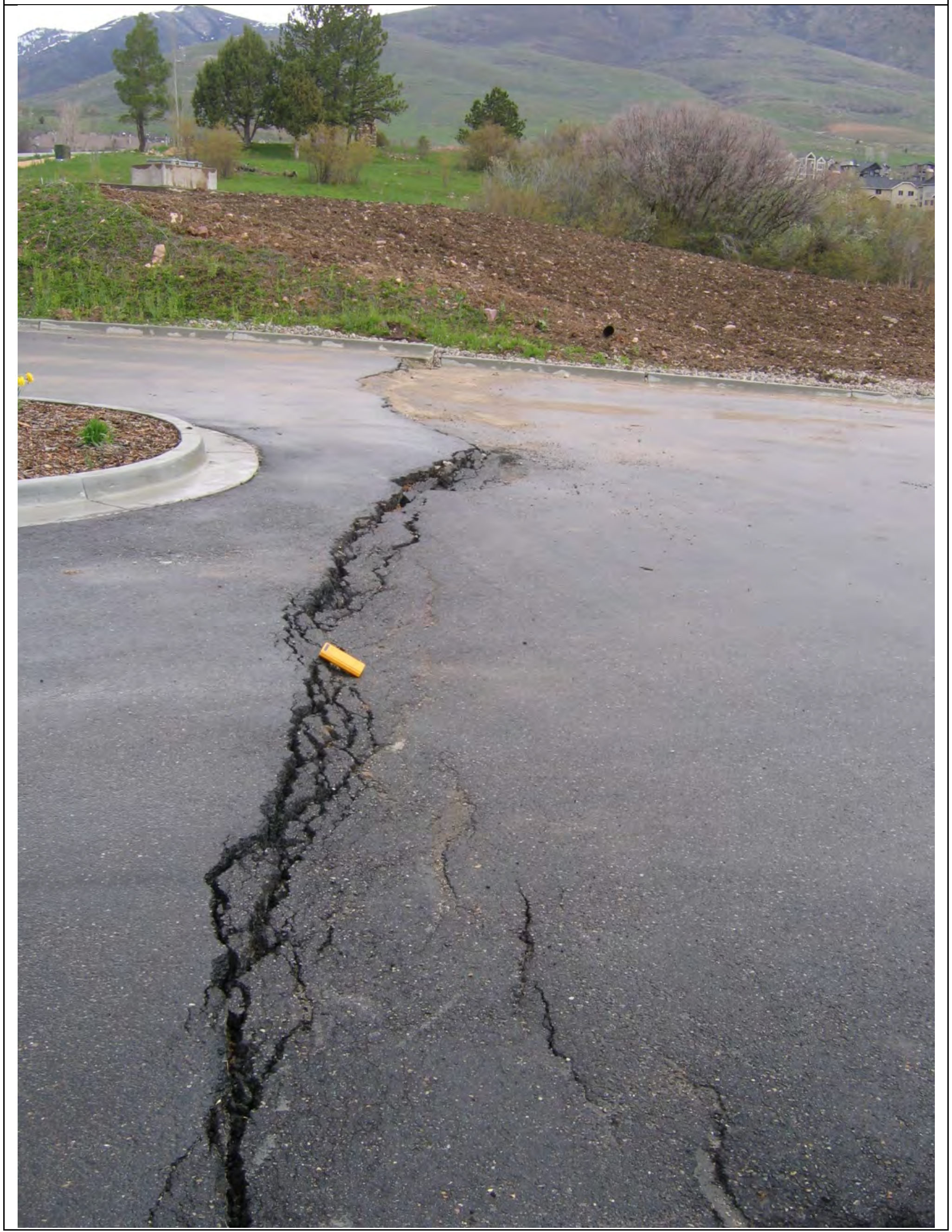


Photo 10. May 2009 UGS site visit. More displacement in parking lot at site.

Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 11. May 2009 UGS site visit. Cracking near storm drain in parking lot.

Photo 12. May 2009 UGS site visit. Scarps in parking lot pavement.

Photo 13. July 2009 UGS site visit. Displacement between gutter and pavement near storm drain.

Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 14. July 2009 UGS site visit. Regraded area with new drain.

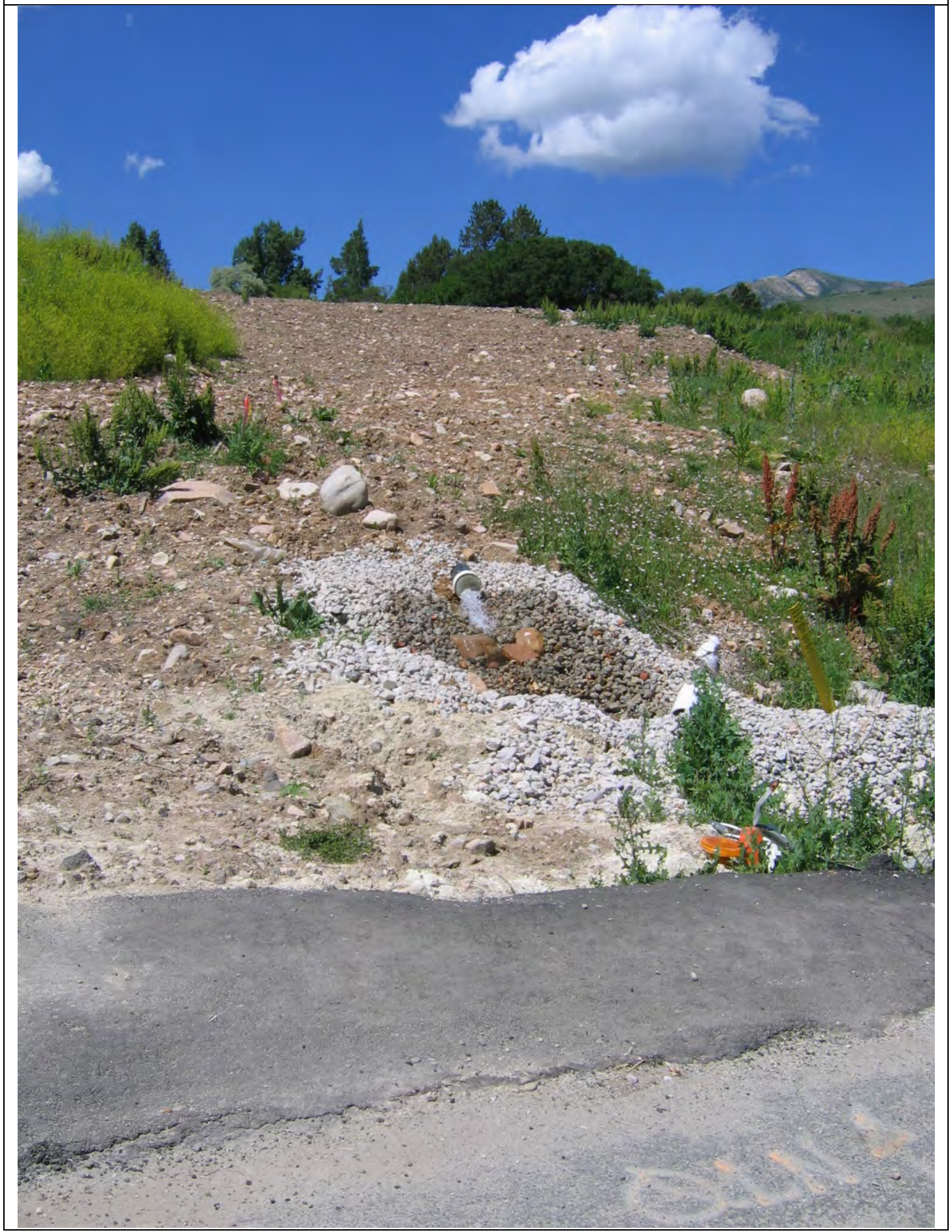


Photo 15. July 2009 UGS site visit. Toe bulge in Moose Hollow Drive.

Photo 16. July 2009 UGS site visit. Obvious toe bulge in Moose Hollow Drive.

Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 17. April 2014 UGS site visit. Drain and new curb and gutter.

Photo 18. April 2014 UGS site visit. Overview of landslide.

Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 19. April 2014 UGS site visit. Back tilting in sidewalk at site.

Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 20. April 2014 UGS site visit. Seepage at toe below water tank.

Photo 21. April 2014 UGS site visit. Repairs? to AC pad.

Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 22. June 2015 UGS site visit. No new displacement at toe.

Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 23. June 2018 UGS site visit. No new movement at site.

Photo 24. April 2019 UGS site visit. No new movement observed.

Photo 25. April 2019 UGS site visit. No new movement observed.

Photographic Record

Welcome Center Subdivision Lot 1 - 3632 North Wolf Creek Drive
Eden, Weber County, Utah

Photo 26. April 2019 UGS site visit. No new movement observed.

Photo 27. Toe area. No new movement compared to Photo 26.

Photo 28. Saw cut pavement repair.

Photo 29. Displacement in transformer pad.

Photo 30. Pull apart between curbing and sidewalk. Compare to Photo 19.

Photo 31. Cracked and displaced roof support.

Photo 32. Pull apart between AC pad and building.

Photo 33. Displacement in AC pad.

Photo 34. Settlement in sidewalk near entrance, but no concrete cracking.

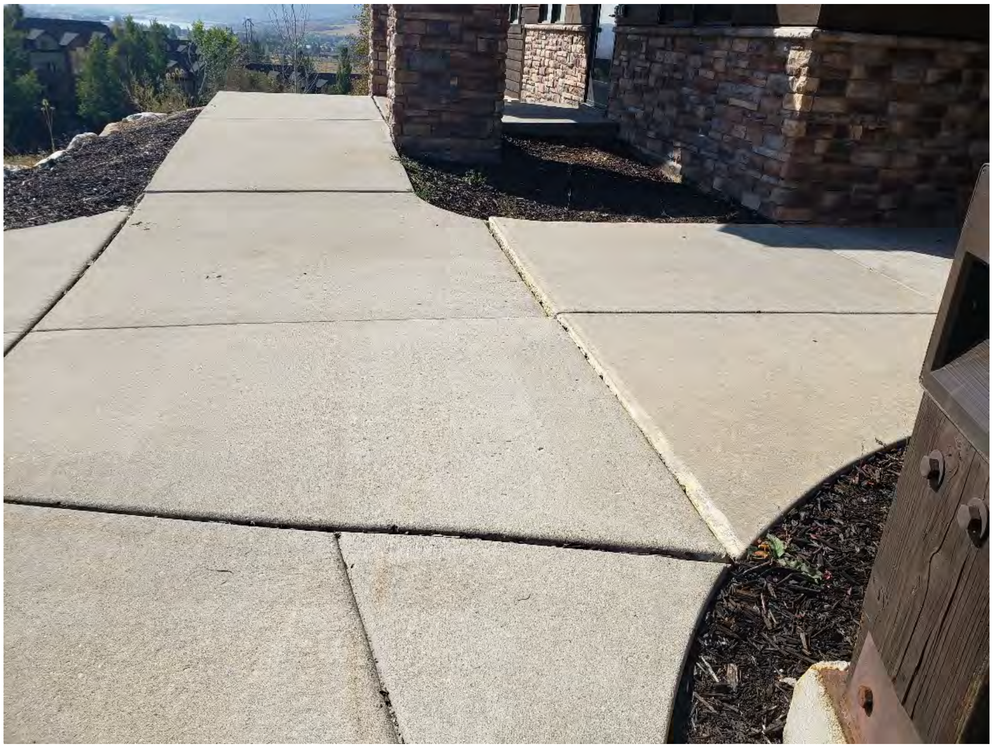


Photo 35. Settlement (tilting) in concrete pad on west side of building.

Photo 36. Gap beneath concrete pad on west side of building.

APPENDIX B

Y2 GEOTECHNICAL REPORT

Y^2 Geotechnical, P.C.
Geotechnical & Environmental Services

P.O. Box 983
Layton, UT 84041-0983
Phone: (801)771-4209 • Fax: (801)771-0561
Toll-Free: 1-866-771-4209
E-Mail: jay@y2geotech.com

June 9, 2006

Ray Bertoldi, AIA
Bertoldi Architects
1186 East 4600 South, Ste 440
Ogden, UT 84403

Subject: Geotechnical Engineering Services
Welcome Center
Wolf Creek
Eden, Utah

Dear Bertoldi,

As requested, Y^2 Geotechnical is submitting this letter addressing the suitability of this site for the above mentioned project. We understand that the project will consist of a commercial building with associated parking lots. The field investigation was completed on June 6, 2006 by a project geologist from our office. The field investigation evaluated the onsite soil conditions and determined the mechanism for the slide located on the eastern side of the proposed development. The laboratory analysis is currently underway and we anticipate the completion of the formal geotechnical study by June 21, 2006. This letter is not intended to take the place of the geotechncial report, but rather to provide an initial evaluation of the suitability of the site for the proposed construction.

Based on the field investigation the site is covered with 10 to 11 ½ feet of uncontrolled clayey gravel with cobbles fill (GC). Below the fill the native soils consist of a clayey gravel with sand and cobbles (GC) which extended beyond the maximum extent of this investigation 12 ½ feet. It was noted that the slide on this site was located at the fill to native soil contact and was likely caused when the area was saturated by the water tank relief line when it had become clogged.

Since the clayey gravel fill at this site is uncontrolled and may be susceptible to large amounts it should be removed from below the building or bypassed. Due to the size of the cobbles at this site it is likely that the fill will need to be removed since deep foundations would be extremely difficult to install.

The uncontrolled fill can be reused beneath the building as long as it is properly placed and compacted. To prevent any sliding failures beneath the building the fill should be placed in level lifts across the entire building pad and if the stability analysis deems necessary the replaced fill along the south and east sides of the building could be reinforced with geogrid reinforcement to provide a wedge of soil beneath the building which could not slide or slump even if the entire hillside on the downhill side were to move. The reinforced wedge would prevent slide failure so that no significant distresses would be noticed in the finished structure.

Due to the fact the lab testing has not been completed, we are unable to determine any exact design parameters and bearing capacities, however we have not encountered any conditions which would make this site unsuitable for the proposed project.

We look forward to continuing to work with you on this project. If you have any questions please call us at 771-4209.

Respectfully,
Y² GEOTECHNICAL, P.C.

6/9/06

RUSSELL JAY YAHNE
No. 324125

R. Jay Yahne, P.E.
Principal Geotechnical Engineer

2 copies sent

Y^2 Geotechnical, P.C.
Geotechnical & Environmental Services

P.O. Box 983
Layton, UT 84041-0983
Phone: (801)771-4209 • Fax: (801)771-0561
Toll-Free: 1-866-771-4209
E-Mail: jay@y2geotech.com

GEOTECHNICAL STUDY
WOLF CREEK WELCOME CENTER
WOLF CR. AND MOOSE HOLLOW DR.
EDEN, UTAH

Prepared By:

Y^2 GEOTECHNICAL, P.C.
2985 NORTH 935 EAST, UNIT 3
LAYTON, UT 84040

(801) 771-4209

Y^2 JOB NUMBER: 06G-80

Prepared for:

RAY BERTOLDI, AIA
BERTOLDI ARCHITECTS
1186 EAST 4600 SOUTH, SUITE 440
OGDEN, UTAH 84403

June 22, 2006

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Y^2 JOB NUMBER: 06G-80

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Y^2 JOB NUMBER: 06G-80

TABLES

FIGURES

LABORATORY RESULTS

1.0 INTRODUCTION

This report presents the results of a geotechnical investigation for the two buildings to be located at Wolf Creek Drive and Moose Hollow Drive in Eden, Utah. The general location of the site, with respect to existing roadways, is shown on Figure No. 1, *Vicinity Map*, at the end of this report.

This investigation was done to assist in evaluating the subsurface conditions and engineering characteristics of the foundation soils and in developing our opinions and recommendations concerning appropriate foundation types, floor slabs, and pavements. This report presents the results of our geotechnical investigation including field exploration, laboratory testing, engineering analysis, and our opinions and recommendations. Data from the study is summarized on Figures 3 thru 6 and in the Laboratory Results.

2.0 PROPOSED CONSTRUCTION

We understand that the proposed buildings will be single story, slab on grade, wood framed structures. We estimate that the maximum loads for the proposed structures will not exceed 6 kips per linear foot for bearing walls, 100 kips for columns, and 150 to 200 pounds per square foot for floor slabs. If structural loads are significantly greater than those discussed herein or if the project is substantially different than described above, our office should be notified so that we may review our recommendations, and if necessary, make modifications.

In addition to the structures described above it is anticipated that utilities will be constructed to service the buildings, that exterior concrete flatwork will be placed in the form of curb and gutter, and sidewalks, and that asphalt parking lot will be constructed.

3.0 CONCLUSIONS

The following is a brief summary of our findings and conclusions:

1. The subject site is suitable for the proposed construction provided the recommendations presented in this report are followed.

2. Based on the two test pits and two field trenches, the site is covered with 10 to 12 feet of uncontrolled silty gravel with sand and cobbles (GM). Below the fill the native soils consist of a stiff fat clay with sand (CH) which extended beyond the maximum extent of this investigation 12 feet. The slide on this site occurred at the contact between the fill and native soil and was likely caused when the area was saturated by the water tank relief line when it had become clogged. Water was not encountered at the time of our site visit.

3. A landslide scarp was examined on the southern slope of the site. The head-scarp has formed at the contact of the semi-compacted fill on the level site pad to the north, and the uncontrolled fill piles that have been dumped over the edge over the years. These fill piles are sliding on the native clay layer that is 10 to 12 feet or more below the current surface. This slide was likely caused when the area was saturated by the water tank relief line when it had become clogged.

?

4. The site is covered with up to 12 feet of uncontrolled gravel fill. This material should be completely removed from below the building. The removed material can then be placed and compacted in 1 foot lifts to return the excavation to design grade.

5. To minimize the potential for sliding occurring at the interface between the building and native soils, the building pad should be cut level into the native soils. The footings should be placed at least 5 horizontal feet into the native fat clays to be through the contact zone.

6. The native fat clay soils are expansive and susceptible to swelling of approximately 2% when wetted.

7. Due to the expansive nature of the native clay soils, all footings and floor slabs should be constructed on at least 24 inches of properly placed and compacted structural fill extended to the undisturbed native clay soils. Standard strip and spread footings may be designed for a maximum bearing capacity of 2,000 psf. More detailed information pertaining to the construction of foundations is provided in Section 10.0, Foundations of this report.

8. Due to the expansive nature of the native clay soils preventing water infiltration below the building will be critical. A subsurface drainage system should be designed to correct and divert water away from the building. Downspouts need to discharge at least 10 feet beyond the backfill. Subsurface drainage is discussed in section 13.0 of this report.

9. Parking lot pavements may consist of 3 inches of asphalt pavement over 6 inches of untreated aggregate base placed on the onsite fill as long as the owner is willing to accept the potential for more extensive and severe distresses pavements. Additional pavement recommendations are stated in Section 14.0 of this report.

10. This investigation was performed with field trenches and a test pit. Section 10.0 of this report provides specific requirements for placement of structures near test pit and trench locations.

4.0 SITE CONDITIONS

The site is an irregularly shaped parcel of land located at the intersection of Moose Hollow Drive and Wolf Creek Drive in Eden, Utah. Currently the site is vacant with a slope of between 4 to 5 percent to the south and is vegetated with weeds, shrubs, and a few trees. The site is bound to the east by a large water tank, to the north by Wolf Creek Drive with residential condominium complexes across the street, to the west and south by Moose Hollow Drive and a vacant field across the street. No water sources or standing water was observed on the site at the time of our investigation.

A landslide scarp was examined on the southern slope of the site. The head-scarp has formed at the contact of the semi-compacted fill on the level site pad to the north, and the uncontrolled fill piles that have been dumped over the edge over the years. These fill piles are sliding on the native clay layer that is 12 feet or greater in depth. This slide was likely caused when the area was saturated by the water tank relief line when it had become clogged.

5.0 FIELD INVESTIGATION

The field investigation was completed on June 6, 2006 by a project engineering geologist from our office. The field investigation evaluated the onsite soil conditions and determined the mechanism for the slide located on the eastern side of the proposed development. The field investigation consisted of digging one test pit to a depth of 10½ feet, and two trenches between 6 and 12 below current site grades at the approximate locations shown on Figure 2 at the end of this report. One trench was located on the eastern property boundary, and the other on the western boundary (Figure 3). The soils encountered at the site were continuously logged by the above mentioned geologist. Due to the nature of the subsurface soils only disturbed samples were obtained and returned to our laboratory for testing.

6.0 LABORATORY TESTING

The samples obtained during the field investigation were sealed and returned to our laboratory where samples were selected for laboratory testing. Laboratory tests included natural moisture determinations, Atterberg Limits tests, grain size distribution analyses, and a remolded swell test. The results of these tests are shown at the end of this report.

Samples will be retained in our laboratory for 30 days following the date of this report at which time they will be disposed of unless a written request for additional holding time is received prior to the disposal date.

7.0 SUBSURFACE CONDITIONS

Based on the two test pits and two field trenches, the site is covered with at least 10 to 11 feet of uncontrolled silty gravel with sand and cobbles (GM). Below the fill the native soils consist of a fat clay with sand (CH) which extended beyond the maximum extent of this investigation 12 feet. The slide on this site was located at the contact between the fill and native soil and was likely caused when the area was saturated by the water tank relief line when it had become clogged. Water was not encountered at the time of our site visit.

Graphical representations of the soil conditions encountered are shown on the Test Pit and Trench Logs, Figures 3 thru 5. The stratification lines shown on the logs represent the approximate boundaries between soil units; the actual transition may be gradual.

8.0 SITE GRADING

8.1 General Site Grading

Prior to construction unsuitable soils and vegetation should be removed from below areas which will ultimately support structural loads. This includes areas below foundations, floor slabs, exterior concrete flatwork, and asphaltic concrete paved roads. Unsuitable soils consist of topsoil, organic soils, undocumented fill, soft, loose or disturbed native soils, and any other deleterious materials. Topsoil and fill were encountered in test pit TP-2 to a depth of 11 feet. Depths of 15 to 20 feet across the site are likely. All topsoil, undocumented fill, or other unsuitable soils should be completely removed.

The site is covered with up to 12 feet of uncontrolled gravel fill. This material should be completely removed from below the building. The removed material can then be placed and compacted in 1 foot lifts to return the excavation to design grade.

8.2 Excavations

Due to the nature of the soils at this site, we recommend that temporary construction slopes for excavations into the native soils or structural fill, less than five feet in depth, not be made steeper than 0.5:1.0 (horizontal:vertical). Excavations deeper than 5 feet should be sloped at 1.0:1.0 or be shored prior to anyone entering the excavation. If unstable conditions or groundwater seepage are encountered, flatter slopes or shoring and bracing may be required. All excavations should meet applicable OSHA[1] Health and Safety Standards for type C soils.

8.3 Structural Fill

If fill is needed, all fill placed below the buildings, pavements, and concrete flatwork should be compacted structural fill. All other fills should be considered as backfill. Structural fill should consist of imported structural material or the onsite fill if all rubbish, construction debris and material over 6 inches in size is removed. The native fat clays are susceptible to swell and should not be used as structural fill. Imported structural fill material should consist of well-graded sandy gravels to silty sands with a maximum particle size of 3 inches and 5 to 20 percent fines (materials passing the No. 200 sieve). The liquid limit of the fines should not exceed 35 and the plasticity index should be below 15. Clean gravel ranging from pea gravel to 6 inches with less than 5 percent fines and sand combined may also be used as structural fill. All fill soils should be free from topsoils, highly organic material, frozen soil, and other deleterious materials.

8.4 Backfill

The onsite fill may be used as backfill in utility trenches and against outside foundation walls as long as all rubbish, construction debris and material over 6 inches in size is removed. The native fat clays are susceptible to swell and should not be used as backfill. Backfill, not under structural elements, should be placed in lift heights suitable to the compaction equipment used and compacted to at least 90 percent of the maximum dry density (ASTM D-1557).

8.5 Fill Placement and Compaction

The thickness of each lift should be appropriate for the compaction equipment that is used. We recommend a maximum lift thickness of 6 inches for hand operated equipment, 8 inches for most "trench compactors", and 12 inches for larger rollers, unless it can be demonstrated by in-place

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[1] Occupational Safety and Health Administration

density tests that the required compaction can be obtained throughout a thicker lift. The full thickness of each lift of structural fill placed should be compacted to at least the following percentages of the maximum dry density, as determined by ASTM D-1557:

TABLE 1: STRUCTURAL FILL COMPACTION

Structural fill	Percent of Maximum Dry Density
Below foundations, flatwork, and pavements:	95%
For fills thicker than 6 feet:	98%
In landscape areas not supporting structural loads:	90%

Generally, placing and compacting fill at a moisture content within 2% of the optimum moisture content, as determined by ASTM D-1557, will facilitate compaction. The further the moisture content is from the optimum, the more difficult it will generally be to achieve the required compaction.

We recommend that fill be tested frequently during placement. Early testing is recommended to demonstrate that placement and compaction methods are achieving the required compaction for the entire depth of fill. It is the contractor's responsibility to ensure that fill materials and compaction efforts are consistent so that tested areas are representative of the entire fill.

Clean gravel fill used as structural fill may be placed in loose lifts up to 2 feet thick. The gravel will need to be compacted with at least 4 passes of a heavy vibratory plate or slow moving vibratory smooth drum compactor. Typically, the gravel will settle 1 to 3 inches when properly compacted, depending on the size and shape of the gravel. Gravel compaction should be verified by either an engineer from Y^2 Geotechnical or a materials testing technician trained in proper gravel placement techniques.

9.0 SEISMIC CONSIDERATIONS

9.1 Faulting

Based on published data, no active faults are known to traverse the site and no faulting was indicated during our field investigation. The nearest known active fault is the Wasatch Fault located about 10 miles west of the property[2].

9.2 Seismic Design Criteria

The structure should be designed in accordance with the IBC building codes. Based on section 1615.1.2 of the IBC and our field investigation, this site is classified as a Site Class C.

9.3 Liquefaction

Liquefaction is a phenomenon where soils lose their intergranular strength due to an increase of pore pressures during a dynamic event such as an earthquake. The potential for liquefaction is based on several factors, including 1) the grain size distribution of the soil, 2) the plasticity of the fine fraction of the soil (material passing the No. 200 sieve), 3) relative density of the soil, 4) earthquake strength (magnitude) and duration, and 5) overburden pressures. In addition, the soils must be near saturation for liquefaction to occur. According to the Weber County liquefaction map, this site is in an area classified as having low risk for liquefaction[2].

10.0 FOUNDATIONS

10.1 Footing Design

The site is covered with up to 12 feet of uncontrolled gravel fill. This material should be completely removed from below the building. The removed material can then be placed and compacted in 1 foot lifts to return the excavation to design grade. The recommendations presented below should be utilized during design and construction of this project:

---

[2] Utah Geologic Survey, Selected Critical Facilities and Geologic Hazards, Weber County, Utah.

1. To minimize the potential for sliding occurring at the interface between the building and native soils, the building pad should be cut level into the native soils. The footings should be placed at least 5 horizontal feet into the native fat clays to be through the contact zone.

2. Due to the expansive nature of the native clay soils, all footings and floor slabs should be constructed on at least 24 inches of properly placed and compacted structural fill extended to the undisturbed native clay soils. Standard strip and spread footings may be designed for a maximum bearing capacity of 2,000 psf. A one-third increase is allowed for short term transient loads such as wind and seismic events. Footings should be uniformly loaded.

3. Continuous and spot footings should have minimum widths of 24 and 36 inches, respectively.

4. Exterior footings should be placed below frost depth which is determined by local building codes. Generally 36 inches is adequate in this area. Interior footings, not subject to frost, should extend at least 18 inches below the lowest adjacent final grade.

5. All structural fill placed below footing should extend at least one half the depth to both side, i.e. 24 inches. Structural fill should extend 12 inches beyond the footing to both sides.

6. Foundation walls on continuous footings should be well reinforced both top and bottom. We suggest a minimum amount of steel equivalent to that required for a simply supported span of 12 feet.

7. This investigation was preformed with test pits and trenches. If a structure is constructed over an uncompacted test pit or trench significant amounts of differential settlement may occur. Test pits typically disturb an area 10 to 20 feet long and 3 to 6 feet wide extending to the depths indicated in the logs. Trenching typically disturbs an area of 10 to 200 feet long, 3 to 6 feet wide, and 5 to 10 feet in depth. If a structure is to be placed within 25 feet of a test pit or trench location, Y^2 Geotechnical should be contacted to verify the structure is not placed over an uncompacted test pit. If a test pit is encountered within the building pad, the disturbed test pit soils should be completely removed and properly placed and compacted structural fill should be used to return the test pit location to design grade. Approximate test pit and trench locations with approximate Pocket GPS coordinates are shown on Figure 2 at the end of this report.

8. Footing excavations should be observed by the geotechnical engineer prior to placement of structural fill and construction of footings to evaluate whether suitable bearing soils have been exposed and verify that excavation bottoms are free of loose or disturbed soils.

10.2 Estimated Settlement

If footings are designed and constructed in accordance with the recommendations presented above, the risk of total settlement exceeding 1 inch and differential settlement exceeding 0.5 inch for a 25-foot span will be low. Additional settlement should be expected during a strong seismic event.

11.0 LATERAL EARTH PRESSURES

Resistance to lateral loads (including those due to wind or seismic loads) on foundations may be achieved by frictional resistance between the foundations and underlying soils, and by passive earth pressures of backfill soils placed against the sides of foundations. Retaining walls and below grade walls acting as soil retaining structures and should be designed to resist pressures induced by the backfill soils.

The lateral pressures imposed on a retaining structure are dependant on the rigidity of the structure and its ability to resist rotation. Retaining walls which are free to rotate at least 0.2 percent of the wall height, develop an active lateral soil pressure condition. Structures that are not allowed to rotate or move laterally, develop an at-rest lateral earth pressure condition. Lateral pressures applied to structures may be computed by multiplying the vertical depth of backfill material by the appropriate equivalent fluid density. Any surcharge loads in excess of the soil weight applied to the backfill should be multiplied by the appropriate lateral pressure coefficient and added to the soil pressure. The lateral pressures presented in Table 2, *Lateral Earth Pressures* below, are based on drained, horizontally placed soils as backfill material. For computing lateral forces we recommend the following equivalent fluid densities:

TABLE 2: LATERAL EARTH PRESSURES

Condition	Static Lateral Pressure Coefficient	Static Equivalent Fluid Pressure (pcf)
Active	**0.28**	**33.9**
At-Rest	**0.44**	**52.9**
Passive	**3.53**	**424.5**

The friction acting along the base of foundations may be computed by using a coefficient of friction of 0.55 for contact with the structural fill. These values may be increased by one-third for transient wind and seismic loads.

The values presented above are based on drained conditions and are ultimate, therefore, an appropriate factor of safety (minimum of 2.0) should be applied to these values for design purposes.

12.0 FLOOR SLABS

Since this site is covered with uncontrolled fill, all fill below the floor slabs should be completely removed and be replaced with properly placed and compacted structural fill or the floor slabs should be structurally supported. For slab design, we recommend a modulus of subgrade reaction of 300 psi/in be used for floors on properly placed and compacted structural fill. To help control normal shrinkage and stress cracking, the floor slabs should have adequate reinforcement for the anticipated floor loads with the reinforcement continuous through interior floor joints and frequent crack control joints.

Special precautions should be taken during placement and curing of concrete slabs and flatwork. Excessive slump (high water-cement ratios) of the concrete and/or improper finishing and curing procedures used during hot or cold weather conditions may lead to excessive shrinkage, cracking, spalling, or curling of slabs. We recommend all concrete placement and curing operations be performed in accordance with American Concrete Institute (ACI) codes and columns.

13.0 SUBSURFACE DRAINAGE

Due to the expansive nature of the native soils, preventing water infiltration below the building will be critical. A foundation drain should be constructed around the building to collect and drain water away. The recommendations presented below should be followed during design and construction of the land drains for the development:

1. The foundation drain should consist of a 4 inch diameter, slotted pipe encased in at least 12 inches of free draining gravel. The gravel should extend up the foundation for 2 feet only. A filter fabric should separate the gravel from the native soils. The pipe should be graded to drain to a storm drain or other free gravity outfall unless provisions for pumped sumps are made. Gravel extending up the walls may be replaced by a fabricated drain panel such as Mirafi Micro drain or equivalent.

2. The highest point of the 4 inch perforated pipe within the foundation drain should be placed at least 6 inches below the bottom of the floor slab. The pipe should be graded to drain (minimum 2 percent grade) to the storm sewer or other free gravity outlet.
3. Clean outs should be installed so that the foundation drain may be cleaned as necessary.

14.0 SURFACE DRAINAGE

Wetting of the foundation soils may cause some degree of volume change within the soil and should be prevented both during and after construction. We recommend that the following precautions be taken at this site:

1. The ground surface should be graded to drain away from the structures in all directions. We recommend a minimum fall of 6 inches in the first 10 feet for landscaped areas and 1 inch in the first 20 feet for paved surfaces.

2. Roof runoff should be collected in rain gutters with down spouts designed to discharge at least 10 feet outside of the backfill limits.

3. Sprinkler heads, should be aimed away and kept at least 12 inches from foundation walls.

4. Provide adequate compaction of foundation backfill i.e. a minimum of 90% of ASTM D-1557. Water consolidation methods should not be used.

5. Other precautions which may become evident during design and construction should be taken.

15.0 PAVEMENT SECTION DESIGN

We understand that flexible pavements are desired for the parking lot within this development. As long as the owner is willing to accept the risk of movement and sever pavement distresses, or a shortened pavement, the new parking lot may be constructed on the existing site fill, otherwise the fill should be completely removed then properly placed and compacted structural fill be used to return the site to design grade. We recommend new pavement sections consist of 3 inches of asphaltic concrete over 6 inches of untreated aggregate road base placed on the onsite fill. The pavement design recommendations were developed using visual and laboratory classification of the on-site soils, an estimated California Bearing Ratio (CBR) of 8 for the supporting fill, assumed traffic for the parking lot of 1,000 vehicles per day with 1 percent being heavier vehicles such as delivery trucks (35,000 equivalent 18-kip loading), the site grading recommendations presented in this report, and the following assumptions:

1. The subgrade is proof rolled to a firm non-yielding condition and soft areas are removed and replaced with structural fill.

2. Grading fills below the pavements and granular borrow meet imported structural fill material and placement requirements as defined in Sections 8.3 and 8.5 of this report, respectively.

3. Asphaltic concrete and aggregate base meet UDOT specification requirements.

4. Aggregate base is compacted to at least 95 percent of maximum dry density (ASTM D-1557).

5. Asphaltic concrete is compacted to at least 95 percent of the laboratory Marshal mix design density (ASTM D-1559).

6. Pavement design life of 20.

16.0 GENERAL CONDITIONS

The exploratory data presented in this report was collected to provide geotechnical design recommendations for this project only. Test pits and trenches were widely spaced and may not be indicative of subsurface conditions between the test pits or outside the study area and thus have limited value in depicting subsurface conditions for contractor bidding. If it is necessary to define subsurface conditions in sufficient detail to allow accurate bidding we recommend an additional study be conducted which is designed for that purpose.

Variations from the conditions portrayed in the test pits and trenches often occur which are sometimes sufficient to require modifications in the design. If during construction, conditions are found to be different than those presented in this report, please advise us so that the appropriate modifications can be made. An experienced geotechnical engineer or technician should observe fill placement and conduct testing as required to confirm the use of proper structural fill materials and placement procedures.

The geotechnical investigation as presented in this report was conducted within the limits prescribed by our client, with the usual thoroughness and competence of the engineering profession in the area. This report is valid only for the location and project described in the report. No other warranty or representation, either expressed or implied, is intended in our proposals, contracts or reports.

We appreciate the opportunity of providing our services on this project. If we can answer questions or be of further service, please call.

Respectfully;

Y^2 GEOTECHNICAL, P.C.
Not official unless stamped and dated

Torrey J. Copfer

Torrey J. Copfer
Project Engineering Geologist

Reviewed by,

LORI S YAHNE
No. 334257
6/22/06

Lori S. Yahne, P.E.
Principal Geotechnical Engineer

3 copies sent

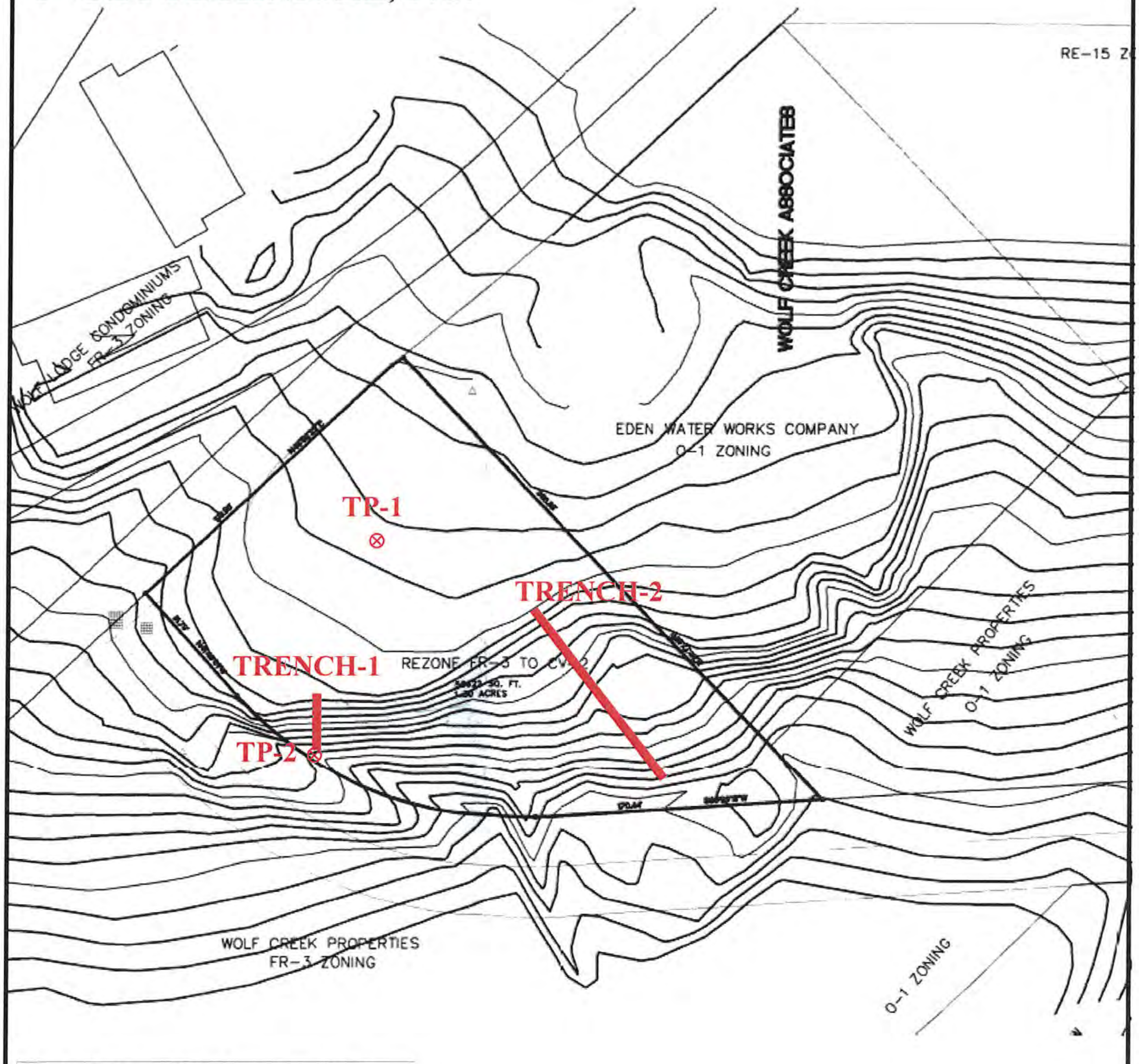
Y^2 GEOTECHNICAL, P.C.

Figure 1: VICINITY MAP

GEOTECHNICAL STUDY
Wolf Creek Welcome Center
Eden, Weber County, Utah

Y^2 Job No. 06G-80

Y² GEOTECHNICAL, P.C.



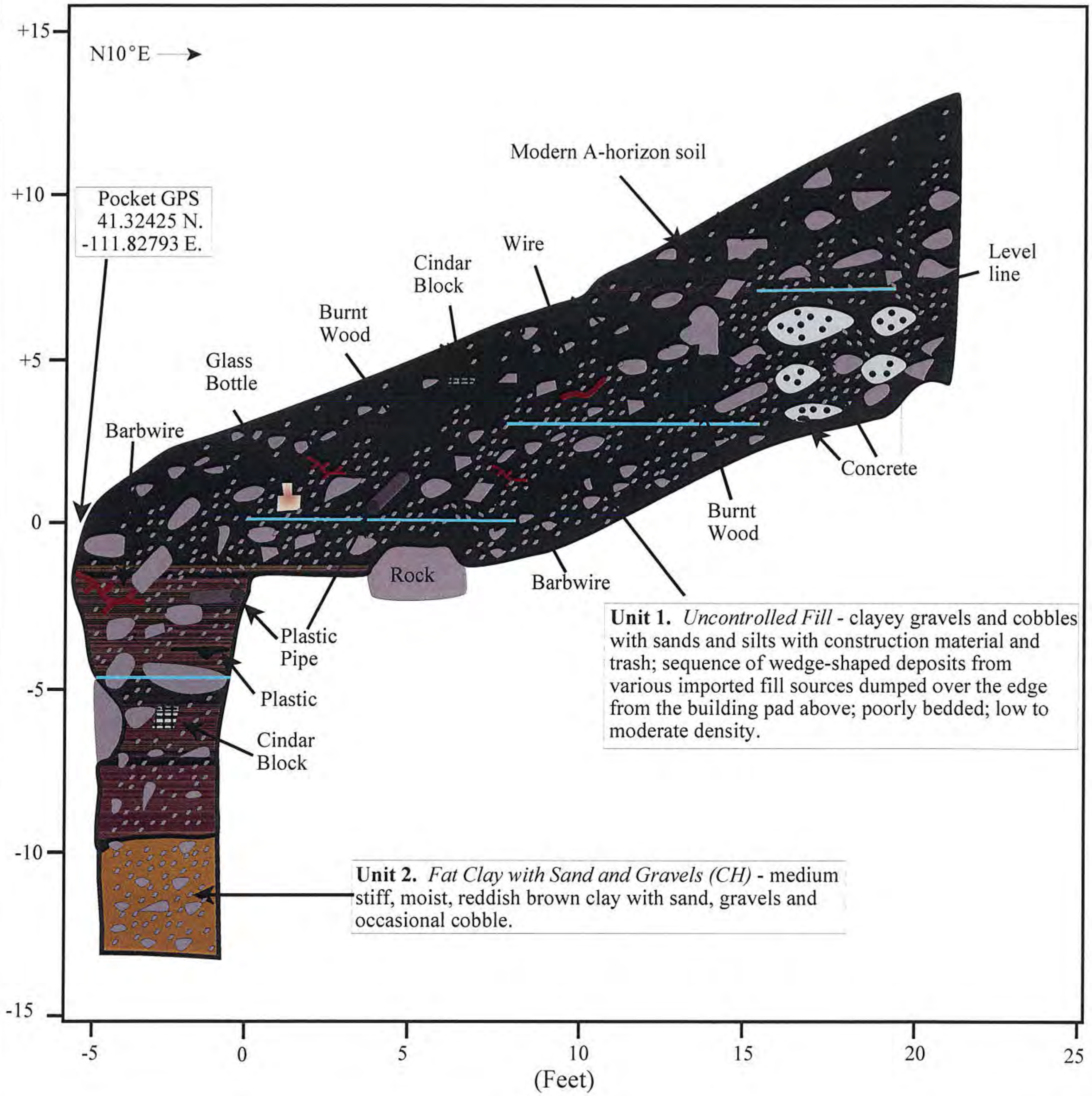
Test Pit ID	Northing	Easting
TP-1	41.32464°	-111.82774°
TP-2	41.32425°	-111.82793°
Trench-2 top	41.32451°	-111.82761°
Trench-2 bottom	41.32431°	-111.82752°

Figure 2: TEST PIT AND TRENCH LOCATIONS

GEOTECHNICAL STUDY
Wolf Creek Welcome Center
Eden, Weber County, Utah

Y² Job No. 06G-80

Y^2 GEOTECHNICAL, P.C.



Unit 1. *Uncontrolled Fill* - clayey gravels and cobbles with sands and silts with construction material and trash; sequence of wedge-shaped deposits from various imported fill sources dumped over the edge from the building pad above; poorly bedded; low to moderate density.

Unit 2. *Fat Clay with Sand and Gravels (CH)* - medium stiff, moist, reddish brown clay with sand, gravels and occasional cobble.

SCALE: 1 inch = 5 feet
(no vertical exaggeration)
West Wall

Logged by Torrey J. Copfer
June 7, 2006
Reviewed by R. Jay Yahne, P.E.

Figure 3: SITE SKETCH OF TP-2

GEOTECHNICAL STUDY
Wolf Creek Welcome Center
Eden, Weber County, Utah

Y^2 Job No. 06G-70

Project No. 06G-80

LOG OF TEST PIT NO. TP-1

Figure 4

PROJECT **Wolf Creek**	CLIENT **Bertoldi Architects**
LOCATION **Wolf Creek Dr. & Moose Hollow Dr. Eden, UT**	Surface Elev.:

Sample type legend: 🖐 Grab Sample

Depth in Feet	Graphic Log	Sample Type	SOIL DESCRIPTION	Moisture Content, %	Liquid Limit, %	Plasticity Index, %	Gravel, %	Sand, %	Fines, %
0	⁘		12" Topsoil with silty sands and gravels- medium dense, slightly moist, brown.						
1	▩		9.5' Fill with silty clay, sands, and gravels - medium dense, slightly moist, brown.						
3	▩	🖐		9.4	NP	NP	54.3	18.4	26.5
4	▩		Boulders encountered at 4 feet.						
7	▩		Yellowish brown clay and gravels.						
8	▩	🖐							
8.5	▩		Moist soils below 8.5 feet.						
10	▩	🖐		11.8	NP	NP	55.2	30.4	13.9
10.5			End of test pit at 10.5 feet.						

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Geotechnical & Environmental Services

WATER LEVELS				
None 6/7/06	STARTED	6/7/06	FINISHED	6/7/06
	EXCAVATION CO.	Wolf Cr. Dvlp.	EQUIP.	310 D
	EXCAVATION TYPE	Backhoe		
	LOGGED BY	Torrey J. Copfer		

Project No. 06G-80

LOG OF TEST PIT NO. TP-2

Figure 5

PROJECT **Wolf Creek**

CLIENT **Bertoldi Architects**

LOCATION **Wolf Creek Dr. & Moose Hollow Dr.**
Eden, UT

Surface Elev.:

🖐 Grab Sample

Depth in Feet	Sample Type	SOIL DESCRIPTION	Moisture Content, %	Liquid Limit, %	Plasticity Index, %	Gravel, %	Sand, %	Fines, %
0		12" Topsoil with silty sands and gravels - medium dense, slightly moist, brown.						
1		11' Fill with silty clays, gravels and cobbles - medium dense, slightly moist, brown.						
3		Glass bottle encountered at 3 feet.						
5		Metal wire encountered at 5 feet.						
5.5		Plastic pipe encountered at 5.5 feet.						
6.5		Plastic encountered at 6.5 feet.						
10		Cindar block encountered at 10 feet.						
11	🖐	Clay with gravels (CL) - medium stiff, moist, reddish brown.	35.6	98	65	5.7	11.9	82.4
12		End of test pit at 12 feet.						

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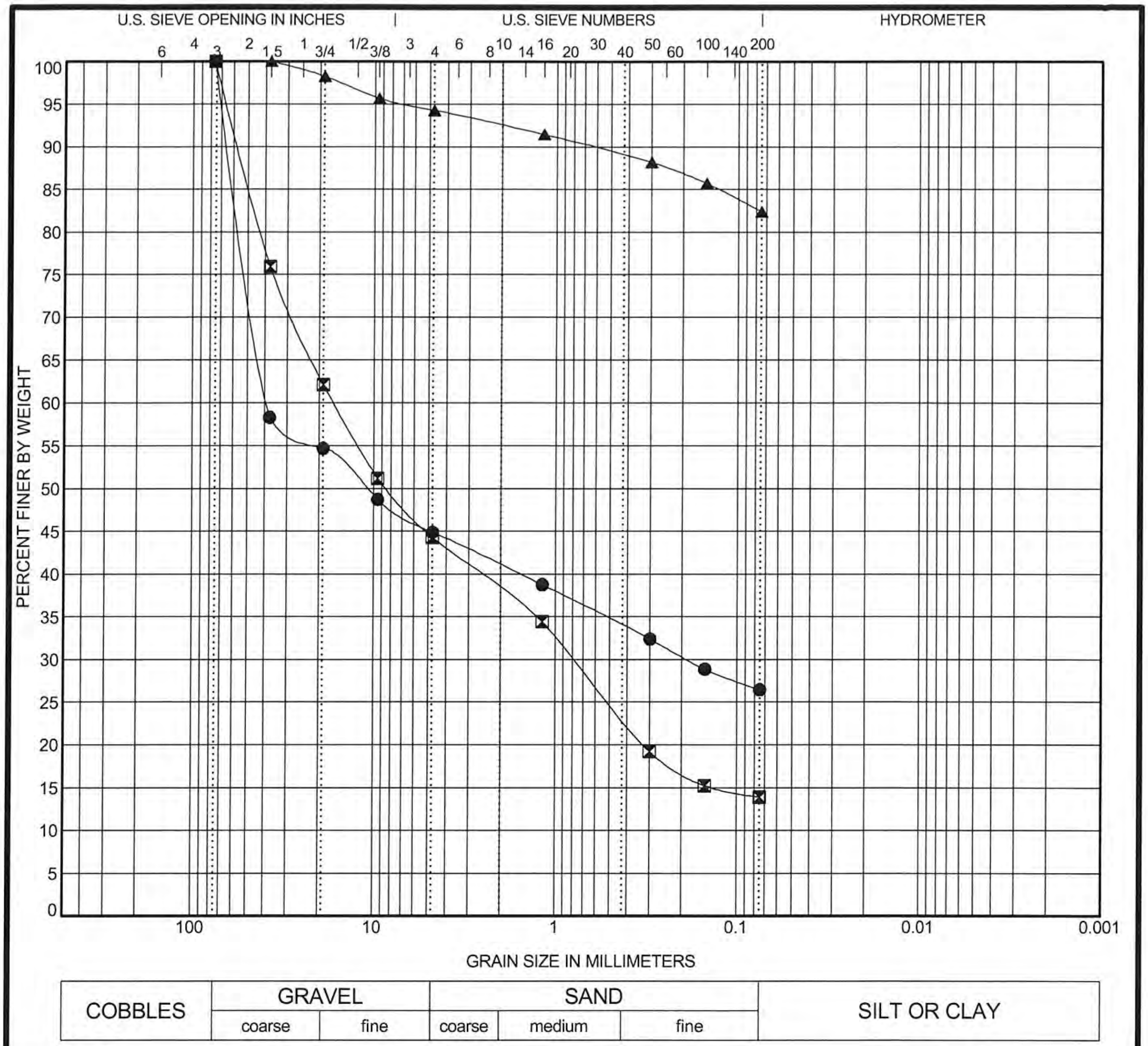
Geotechnical & Environmental Services

WATER LEVELS	STARTED 6/7/06	FINISHED 6/7/06	
None 6/7/06	EXCAVATION CO. Wolf Cr. Dvlp.	EQUIP.	
	EXCAVATION TYPE Trackhoe		
	LOGGED BY Torrey J. Copfer		



Specimen Identification			Classification	LL	PL	PI	Cc	Cu
●	**TP-1**	**3.0**	**SILTY GRAVEL with SAND(GM)**	**NP**	**NP**	**NP**		
☒	**TP-1**	**10.0**	**SILTY GRAVEL with SAND(GM)**	**NP**	**NP**	**NP**		
▲	**TP-2**	**11.0**	**FAT CLAY with SAND(CH)**	**98**	**33**	**65**		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**TP-1**	**3.0**	**76**	**38.58**	**0.19**		**54.3**	**18.4**	**26.5**	
☒	**TP-1**	**10.0**	**76**	**16.58**	**0.79**		**55.3**	**30.4**	**13.9**	
▲	**TP-2**	**11.0**	**37.5**				**5.7**	**11.9**	**82.4**	

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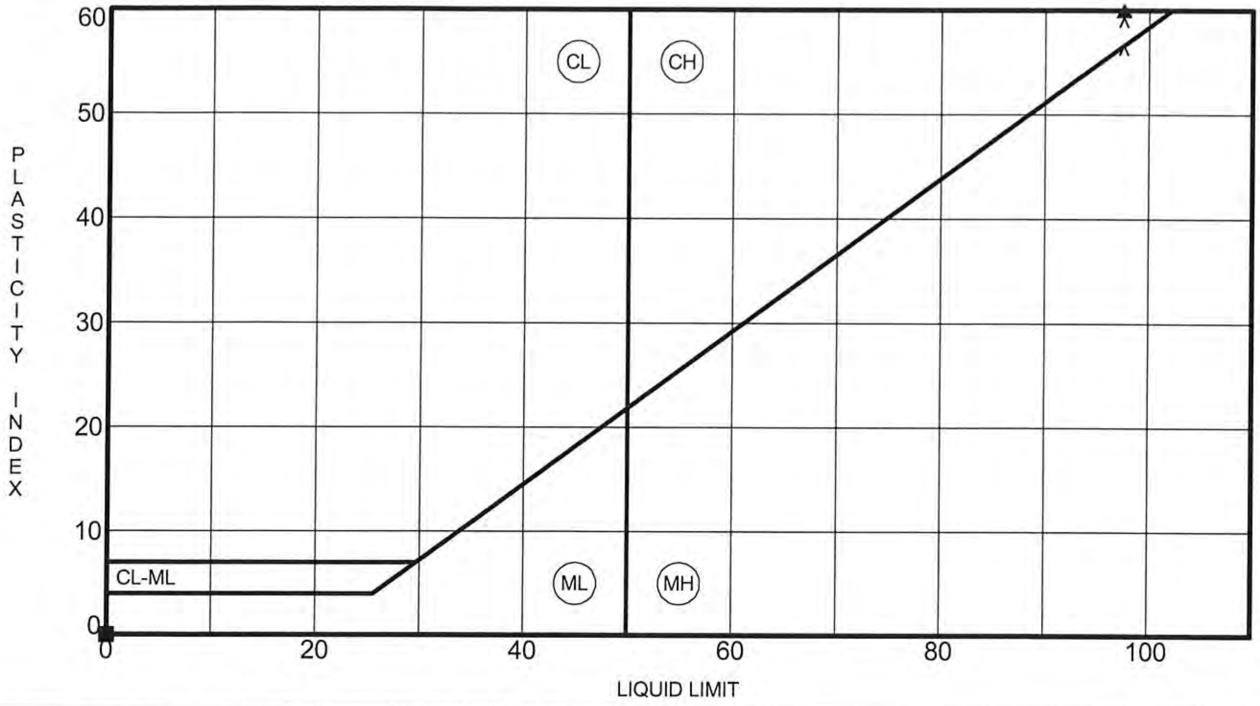
Geotechnical & Environmental Services

GRAIN SIZE DISTRIBUTION

Project: Wolf Creek
Location: Wolf Creek Dr. & Moose Hollow Dr. Eden, UT
Number: 06G-80

US GRAIN SIZE 06G-80 WOLF CREEK.GPJ Y2 GEOTECH.GDT 6/22/06



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**TP-1**	**3.0**	**NP**	**NP**	**NP**	**26**	**SILTY GRAVEL with SAND(GM)**
☒	**TP-1**	**10.0**	**NP**	**NP**	**NP**	**14**	**SILTY GRAVEL with SAND(GM)**
▲	**TP-2**	**11.0**	**98**	**33**	**65**	**82**	**FAT CLAY with SAND(CH)**

US ATTERBERG LIMITS 06G-80 WOLF CREEK.GPJ Y2 GEOTECH.GDT 6/22/06

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Geotechnical & Environmental Services

ATTERBERG LIMITS' RESULTS

Project: Wolf Creek

Location: Wolf Creek Dr. & Moose Hollow Dr. Eden, UT

Number: 06G-80

Sheet 1 of 1

Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	Maximum Size (mm)	%<#200 Sieve	Class-ification	Water Content (%)	Dry Density (pcf)	Satur-ation (%)	Void Ratio
TP-1	3.0	NP	NP	NP	76	27	GM	9.4			
TP-1	10.0	NP	NP	NP	76	14	GM	11.8			
TP-2	11.0	98	33	65	37.5	82	CH	35.6			

Y^2 Geotechnical, P.C.

Geotechnical & Environmental Services

Summary of Laboratory Results

Project: Wolf Creek

Location: Wolf Creek Dr. & Moose Hollow Dr. Eden, UT

Number: 06G-80